FOREWORD

WE hear much of "wonders" in these days, surrounded as we are by man-made marvels, all too few of which are properly appraised by most of us. And despite the enormous educational and cultural advances of the past half century there are many of Nature's wonders and beauties that lack a full and proper appreciation. The aim of "The World's Wonders" is to serve as an eye-opener—to bring vividly before readers the wonder and majesty and splendour of Nature's achievements, and to indicate what man himself has done in various fields of engineering and invention.

We live in what has not inaptly been termed the "push-button" age of automatic mechanisms; we do less and less with muscle and sinew and have come to rely more and more on "servo mechanisms." We throw over a switch or move a lever and the machine does the rest, whether it be the selection of a telephone number at the distant automatic exchange, the direction and control of a lift, or the operation of the mighty gates that give access to an inter-ocean canal. One great result of all this machinery is more leisure. The worker to-day enjoys leisure undreamt of but a few decades ago, and one important use he makes of his new-found freedom is to read such works as "The World's Wonders." A striking feature of intellectual life to-day is the avid desire for more knowledge about the world in which we live—not the dry and dull information that is got from works of reference, but a fuller and more vivid presentment, like that given by a traveller who returns from his journeys of exploration and research full of the wonder of what he has seen ; or that first-hand account of some epoch-marking discovery which from time to time is given to the world by a scientist.

For a number of years it has been my task—and I could not wish for a more fascinating one—to describe and explain the achievements of the pioneer, the inventor, the engineer and the scientist; to expound the marvels all around us. In "The World's Wonders" a panorama is displayed, an attempt being made to describe wonders of land and sea and sky, of the denizens of these realms, and of some of the mighty and complex machines man has contrived in order to obtain the mastery of his three kingdoms. Nature set boundaries to his travel, but he built bridges, dug canals, and burrowed out enormous tunnels that made a sport of Nature's ditches and ramparts and barricades. On great waterways where falls and cataracts barred navigation, he made a by-pass canal and circumvented the obstruction. More wonderful still, he utilised the gigantic latent fund of energy in the fall to provide light and warmth and motive power for vast regions around.

The Seven Wonders of the Ancient World have been depicted for the reader, so that he may visualise these great achievements of the past. The Great Pyramid of Gizeh alone remains to-day : gone are the Hanging Gardens of Babylon, the Statue of Zeus by the incomparable sculptor Pheidias, the Tomb of Mausolus, the Temple of Diana at Ephesus, the Colossus of Rhodes, and the Pharos of Alexandria. The choosing of Seven

Modern Wonders was no easy matter; we illustrate Battersea Power Station, standing for the manifold electrical achievements of our day; New York in the glory of its blaze of illuminations; the Q.S.T.S. *Queen Mary*, a stupendous feat of marine engineering; the "Cheltenham Flyer," a symbol of safe and rapid transport on the iron road; the Macchi-Castoldi seaplane in which the world's record speed of 440 miles an hour was attained; and Sydney Harbour bridge, with its enormous span. The Seventh Wonder is represented by a photograph of a film studio, for what indeed could be more marvellous than the talking picture, in which the resources of electrical and photographic invention have combined in a prolific partnership?

As to the colour plates themselves, little need be said; whether portrayed by brush or by camera, their beauty is self-evident. Felix Gardon's interpretation of the Seven Ancient Wonders, based upon such evidence, mainly literary, as exists, bespeaks a labour of love and a fine appreciation of his task. The photographers that lent their art to depict the Modern Wonders have been just as successful, and these brilliant camera studies are remarkable in many respects. For permission to reproduce the delightful and fascinating picture of a forest of long, long ago we are indebted to the artist, Walter E. Spradbery, and to the British Museum of Natural History. This fine study of the luxuriant vegetation of the Carboniferous Period should be examined in the light of the vivid pen picture given in Chapter XXV, "When the World was Young." We can almost hear "the drowsy murmur of the wind in the fronds of the great ferns," and the crash of the monstrous plants as from time to time they fall prostrate.

The hundreds of photographs with which "The World's Wonders" is illustrated have been chosen with great care for their beauty and fitness; and one point especially regarding them we wish to emphasize. The air camera has endowed the reader of to-day with a new faculty—the vision of the bird. We can now see, in the safety and comfort of our homes, what the airman sees when he flies over tropical jungle, great city or desert waste. Air photography, in fact, has opened up a new phase of illustration, and wherever in this volume it has been considered that an air photograph would increase the interest or give the most comprehensive impression of a subject, such a photograph has been reproduced. The test of this policy lies, of course, in its value to the reader and it is for him to judge from the seventy illustrations of the kind included in this work.

The eleven authors whose names appear on the title page were given a free hand to paint word pictures of the Wonders they were qualified to describe, and each has used that verbal style which seemed fittest for his purpose. The various Chapters thus present a pleasing variety, both of subject matter and of language. That the perusal of this work may afford as great pleasure as its compilation has done is the hope of

THE EDITOR.

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THE WORLD'S WONDERS

WONDERS OF THE SEA

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CHAPTER I

LIFE BENEATH THE WAVES

THE sea has always fascinated the mind of man, for over and above its majestic beauty, its stupendous power and matchless variety of mood, it is a realm of inviolable mystery, a fairy-like domain of which man, with all his ingenuity, can never hope, perhaps, to do more than merely cross the threshold.

The life of the ocean is at once profoundly secret and incredibly vast. It is a world within a world, an immense storehouse of organic energy; and our placid, smiling bays and desolate wastes of grey water hold life in a fuller variety and abundance than can be found in the most luxuriant jungle or tropical forest.

Giant Mammals of the Ocean

Of all the wonderful creatures of the sea—from the minute diatoms and infusoria upwards—none has attracted the attention of mankind more than whales, which long before the days of Jonah had impressed the popular imagination with their size and strength. The plain facts concerning whales and their kindred are wonderful enough, and so it is not surprising that in the course of centuries such fantastic and apocryphal stories gathered round the "leviathan" that it became literally a beast of fable; in fact, it is only comparatively recently that whales have been studied through the eyes of science.

It is unnecessary, perhaps, to state that a whale is not a fish, as was at one time universally believed, but a mammal, the female bearing her young in a highly developed state and feeding it with her own milk.

Students of evolution have put forth a very wonderful history of the development of whales. Countless centuries ago, in the remote geological era known as the Tertiary period, a number of mammals took to devouring fish, molluscs and other creatures which they caught in fresh-water pools and shallows. Gradually they grew bolder, pursuing their prey into the water itself, where eventually they felt completely at home; the intervals which they spent on land became shorter and shorter until, with the lapse of many thousands of years, these ancestral whales ended by becoming entirely aquatic animals, and swimming down the rivers entered the open sea, which the majority of them have inhabited ever since.

The Evolution of Whales

Meanwhile, their bodies had become modified in a marvellous way to suit the changed conditions, growing fish-like or "streamlined" and losing their hairy covering, which would be cumbrous and useless in the water. The fore limbs were changed into flattened paddles for cleaving the water, while the tail spread out into two huge and immensely

powerful horizontal lobes, forming a perfect device for swimming and diving. The hind limbs, on the other hand, became superfluous and eventually disappeared, though it is interesting to note that in the skeleton of the modern whale these aborted limbs are still represented by insignificant particles of bone attached to the shrunken remnants of the pelvis; while very rarely a whale has been known to possess rudimentary hind limbs growing on the outer surface of its body—a remarkable instance of a "throw-back" to a remote ancestral characteristic.

How the Whale Keeps Warm

Again, in the course of its development from a land animal, the whale's nostrils have shifted to the top of its head, so that the creature may breathe without being obliged to lift an inconvenient amount of its body above the water; while the normal coating of fat possessed by every mammal has been converted into a dense, insulating layer of "blubber," as much as 18 inches thick, whose function it is to maintain the temperature of this warm-blooded animal in the icy seas in which it has made its home. Altogether, the whale is a marvellous example of adaptation to environment.

In regard to the whale's nostrils or "blowholes," of which there may be one or a pair, according to the species in question, situated as we have seen on the top of its head, there have been several erroneous ideas. The popular belief is that the whale is, for some obscure reason, in the habit of ejecting a fountain of water from this hole. But in reality it is only emptying its capacious lungs of exhausted air, preparatory to taking a fresh breath. This exhausted air is expelled with force from the animal's nostril, and the warm water vapour with which it is laden is, on meeting the cold atmosphere, instantly condensed into a column of white steam, which from a little distance has all the appearance of a fountain of water. If the whale begins his "blow" before he has quite broken the surface of the sea, a little water may be carried up with the jet of air, thus assisting the illusion.

Whales can be separated into two principal divisions, i.e. those with teeth and those in which teeth have been superseded in the long course of development by the curious flexible plates known as "baleen," or whalebone; yet the young of even the whalebone whales are provided before birth with rudimentary teeth, though these never appear above the gum and are eventually absorbed, to be replaced later with baleen. This substance is one of the greatest curiosities of Nature; briefly, it consists of a number of flat, horny plates, hanging down, one behind the other, on each side of the animal's mouth and varying in colour from a creamy white to the deepest black. Above, each of these plates widens considerably and is embedded firmly in the roof of the mouth. The lower part forms the apex of a rough triangle and is not attached to the mouth; while the inner edge of each plate is fringed out into a mass of long, soft and very coarse hairs. There are nearly four hundred of these plates, ranged one behind the other on each side of the enormous mouth.

Now let us see the use of this remarkable apparatus. The Greenland whale, in which baleen is seen at its fullest development, feeds entirely upon minute crustaceans that swim so thickly in the Arctic seas that their ruddy tint stains the water for mile upon mile—though, of course, it requires an enormous quantity of these tiny creatures to satisfy the whale's huge appetite. It has solved its food problem in its own inimitable way. Swimming through a shoal of these tiny creatures, it opens its cavernous mouth to admit a huge volume of water, then closes its jaws, raises its enormous tongue, and so squirts out the water through the plates of baleen, which act as a most efficient strainer, while a strange assortment of prey is left behind to be swallowed at leisure.

Human ingenuity has found many uses for the whale's great sieve. In the Middle Ages baleen was in demand for the plumes on the helmets of armoured knights and later was used to make brushes and the frames of umbrellas and to stiffen crinolines, bonnets and corsets; but to-day the peculiar properties of whalebone—especially its lightness, toughness and elasticity—are almost entirely furnished by steel, and so the demand for this product has diminished considerably. Whalebone of the best quality, furnished almost entirely by the great Greenland whale, has been known to fetch nearly £3,000 per ton, and when it is realized that an average specimen can easily furnish half this quantity, it is not surprising that these splendid whales have become almost extinct by excessive hunting.

The Right Whales

The Greenland whale, which is also known as the Arctic right whale, or bowhead, attains a length of 50 feet or more, about one-third of which consists of the head, with its great

baleen plates. This enormous creature cruises about among the ice-floes of the Far North, moving along with powerful up-and-down strokes of its broad tail. Apart from its valuable baleen and blubber, its flesh provides the Greenlanders with meat; the chief delicacy is the gum in which the whalebone is embedded, which is said to have a flavour like that of the best cream cheese, while the thick, black skin of the animal also is eaten.

A closely related species, the black whale, or Southern right whale, inhabits warmer seas; it can be distinguished from its northern cousin by its smaller head and shorter whalebone. In the North Pacific is found the great grey whale, from 40 to 45 feet in length, which has the shortest and coarsest whalebone of all. More active than any of these is the humpback whale, which inhabits most of the seas of the world, and is one of the principal species sought by the modern whaler. Apart from the small triangular fin on its back and its long flippers, designed for speed, the humpback is distinguished by several rows of curious bony knobs upon the top of its head and also by the fact that the skin covering its throat and chest is pleated into numerous longitudinal folds which enable the cavity of the mouth to be extended enormously when the whale is feeding, and which, at the same time, provide a lodging for innumerable parasites.

These curious throat pleats also characterize the finner-whales, or rorquals, which are the most cosmopolitan of whales, being found in almost every sea; incidentally they form a very large proportion of those whales that every now and then are cast upon the shores of the British Isles. Rorquals vary considerably in size, but they include among their number the largest species of animal that has ever existed in the whole history of the world, extinct animals included. This is Sibbald's rorqual, also known as the blue whale, or "sulphur-bottom," which has been known to attain a length of 120 feet. One of these gigantic beasts that was stranded upon the coast of our own islands had a total length of 95 feet, with a breadth of 18 feet; each of its fins was 12½ feet long. Its bones,

As a result of stormy weather and abnormal tides, whole schools of whales are sometimes driven ashore and left stranded. Here are 300 of the great creatures lying helpless at Stanley on the north-west coast of Tasmania

when dried, were found to weigh 35 tons, while the total weight of the carcass was estimated at about 250 tons. The blue whales begin their lives as giants, being about 30 feet long at birth, and even when they are nearly 70 feet in length they are generally still at the suckling stage—undoubtedly the largest of all infants! The appetite of these leviathans is in proportion, and in the stomach of one blue whale were found six hundred large codfish, with an immense quantity of other food, for rorquals do not restrict their diet to minute sea life as do the right whales.

In general, rorquals are more slender and more active than the right whales, and the larger species display amazing strength and endurance. A well-grown specimen of Sibbald's rorqual, for instance, even though badly wounded, has been known to tow a whaling steamer with engines reversed for the best part of twenty-four hours. Frequently these great whales snap the tough harpoon lines as though they were thread, and make their escape; and it is recorded that one blue whale, making its first dive after being harpooned, ran out nearly 3,000 feet of line within a minute, and ultimately escaped from its pursuers.

The common rorqual is a smaller animal than the blue whale, and ranges through more southerly waters. Smaller still are Rudolphi's rorqual and the lesser rorqual, attaining an average length of about 45 feet and 25 feet respectively; the latter species is distinguished by its sharp, beak-like nose. All these animals are occasional visitors to our shores, and all of them are hunted for their blubber, oil and baleen, though the latter is inferior in quality compared with that of the right whales.

Treasures from the Sperm Whale

Of the second great group of whales—those that are provided with teeth instead of baleen—by far the most important economically is the sperm whale, or cachalot, which furnishes mankind with several valuable products. A remarkable feature of this whale is its enormous head, which occupies about one-third of the animal's total length and terminates in a blunt, truncated snout. The lower jaw is comparatively small and narrow, and it is armed with about twenty-five peg-like ivory teeth on each side. There are no visible upper teeth, although they exist in a rudimentary state within the gum; and the sperm whale's mouth is obviously not adapted for chewing, but only for seizing its slippery prey, which consists of large fish, squids and cuttlefish.

The enormous barrel-like head of the sperm whale—known in the whaling industry as the "case"—is almost entirely filled with oil. This is ladled out of the carcass in buckets, and on cooling there separates from it the white, waxy substance known as spermaceti. The remaining fluid—sperm oil—is the most valuable and important of all the oils produced by whales, being used in the lubrication of delicate machinery. As much as twenty-four barrels of spermaceti and nearly a hundred barrels of sperm oil have been obtained from the head cavity of an average-sized cachalot.

Whalers consider themselves in luck whenever their quarry yields some of the greatly prized ambergris. This dull grey, pleasant-smelling, waxy substance is produced only in the intestines of the sperm whale, though occasionally lumps of it are found floating in the sea. It is a morbid product—the result, so to speak, of an acute attack of indigestion—and it often contains the hard, horny beaks of cuttlefish that have been devoured by the sperm whale. Ambergris, which in medieval times had an honoured place in the menu of princes and wealthy men, is to-day almost exclusively used in perfumery to reinforce the odour of more volatile substances. More than £13,000 has been paid for a lump of ambergris weighing about 250 pounds.

Beaked Whales and Dolphins

The curious beaked whales have both jaws prolonged into a tapering snout; as a rule they have two teeth only, embedded in the lower jaw. In the species known as Layard's whale, these teeth, growing steadily throughout life, curve over the narrow upper jaw and hamper its movements in a way that must be distinctly embarrassing to the owner, who not infrequently perishes of starvation through being unable to open his mouth!

Of the important family of toothed whales known as Delphinidæ, or dolphins, one of the most common is the familiar porpoise of British waters, herds or "schools" of which can often be seen playing about off shore or following shoals of mackerel or pilchards, on which these active whales largely feed. By the people of the Middle Ages the porpoise was itself eaten extensively, being accounted no mean delicacy; but nowadays it is useful chiefly for its tough, leathery hide. The common porpoise averages about 5 feet in length; it has a low back fin and a rounded,

cod-like mouth, and its ear, situated just behind the small eye, is a bare pin-prick. It has numerous well-developed teeth in either jaw.

Another important member of the dolphin tribe is the beluga, sometimes called the white whale, since it is practically white all over. The beluga is a native of the cold Arctic seas, but it is fairly common in the River St. Lawrence, and specimens are occasionally washed ashore in the British Isles. The beluga rarely exceeds 12 feet in length, and it is one of the very few whales whose size permits them to be kept in captivity.

Most of the whales we have described, even the largest and most powerful, are mild and inoffensive creatures, feeding chiefly on fish and minute marine organisms, and desiring only to be left undisturbed. Of a very different character, however, is the formidable grampus, or killer, one of the terrors of the deep. Twenty feet or more in length and of great strength and ferocity, the grampus, *disdaining smaller prey, feeds voraciously on* seals, porpoises and belugas, and many individuals will unite together in large packs to hunt down their quarry. The remains of as many as fourteen porpoises and a similar number of seals have been found in the stomach of a single killer: and so great is the terror of the smaller whales when a school of killers is on the prowl that they will fling themselves ashore in large numbers *in an endeavour to escape the teeth of these* remorseless enemies. It is said that the killer will not hesitate to attack even the huge Greenland right whale, but, catching it by the lip, drags it below the water, there to devour its great tongue.

The last whale which we shall describe is also one of the most remarkable. This is the narwhal, or "sea unicorn," which carries, projecting from its upper jaw, a long, straight and tapering tusk of ivory, marked with a spiral twist. This formidable spear is nothing more nor less than the narwhal's left tooth, which continues to grow throughout life, eventually attaining a length of 8 or 9 feet, or about two-thirds that of the rest of the animal's body. The corresponding tooth on the right-hand side is rarely developed but remains sunk invisibly in its socket. Except for these two teeth, the *adult narwhal has no others in its head,* though the young have several rudimentary ones, which later disappear; moreover, in the female both teeth are invisible, remaining almost invariably sunk beneath the gum in an undeveloped state.

Narwhals swim about in schools of twenty or so among the Arctic ice floes, where their food—largely cuttlefish and small crustaceans—abounds, but occasionally specimens are stranded upon the British coasts.

The function of the narwhal's curious tusk has been much disputed, though it is improbable that it is used for fighting or for killing prey. In China narwhal's tusks are ground up as medicine, and in Europe they were at one time prized as walking canes, while the ancient kings of Denmark are said to have been crowned upon a throne made entirely of this strange ivory.

The old whaling ships were stoutly built wooden vessels of about 350 tons burden. As soon as a whale was sighted the boats were lowered in pursuit, each boat being equipped with about 400 fathoms of line, carefully coiled in wooden tubs. The whale was approached as silently as possible, and at a few yards' distance the steel harpoon, razor sharp, was cast by hand. Then came a moment of danger and excitement, for the huge animal, maddened with pain and fury, would not infrequently turn on its pursuers, endeavouring to smash their boat with blows of its powerful tail. More usually, however, it would "sound," or dive, immediately it felt the harpoon, sometimes remaining below water for the best part of an hour; or it would set off at a great speed in an endeavour to escape, the boats following and the line being paid out very carefully, for the least hitch might result in the capsizing of the boat. A powerful whale has been known to run out more than two miles of line. When the whale's strength was exhausted, the line was gradually hauled in, and then the *coup de grâce* was given with lances. Having been pumped full of air to keep it afloat, the carcass was lashed to the side of the ship for the operation of "flensing," or securing the blubber, oil and whalebone.

Modern whalers use essentially the same

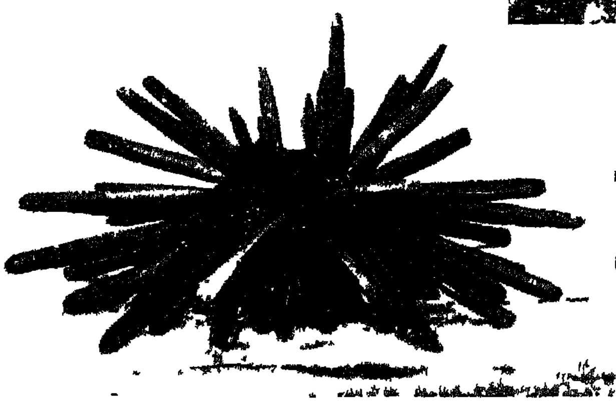
their own. The body is rotund and spindle-shaped, tapering rather sharply backwards towards the large and powerfully developed tail. The opening of the mouth is usually placed on the under-side of the body, some distance from the tip of the snout, so that some species are obliged to turn upon their backs in order to swallow large prey. And it is rather a surprise to note that the bulk of the dreaded shark's skeleton is not composed of bone, as we might expect, but of comparatively soft and yielding cartilage.

Man-eating Sharks

The ferocious man-eating sharks are natives of warm seas, where they may attain a

length of thirty feet or more, though in regard to size they are far outclassed by a somewhat uncommon species known as the chagrin, from the Indian Ocean, which is said to reach the prodigious length of 70 feet. This, again, would appear almost diminutive beside that of some ancestral sharks, fortunately long since extinct and fossilized, which measured nearly 100 feet from nose to tail. These fearful creatures must have been extremely abundant, for large quantities of their enormous fossilized teeth are quarried in Florida, to be converted into artificial manure.

Sharks are greedy and voracious feeders, devouring enormous quantities of fish and other marine animals, and all too often wreaking considerable mischief in fishing-grounds. In the stomach of a white shark



—a dreaded man-eater—there have been found the remains of a small sea lion weighing 100 pounds; while the related blue shark, though not directly harmful to man, may cause great loss to fishermen. Much to the alarm of bathers, this species often appears off the coasts of the British Isles, but it is comparatively small, seldom exceeding 6 feet in length. Another species common off the

Photos Otho Webb Embury Barrier Reef Expeditions

All spikes, spines and prickles, the Sea-urchin is beautiful to some purpose, for it is this defensive covering which saves it from being devoured by enemies. *Top:* Short-spined Sea-urchin; *left:* Slate-pencil Sea-urchin; *bottom:* Needle-spined Sea-urchins

shores of our islands is the porbeagle, or Beaumaris shark, which may grow to 10 or 12 feet in length, though usually it is much less. The porbeagle feeds on cuttlefish, herrings and pilchards and does not attack man; in the countries bordering the Mediterranean it forms a valuable article of human diet.

An Original Method of Hunting

The fox shark, or thresher, is another frequent visitor to British waters, and is regarded by our fishermen as a great pest on account of the havoc which it causes to fishing-tackle and among shoals of fish.

The thresher reaches a length of 15 feet, much of which is contributed by its greatly elongated tail. Its method of hunting is ingenious and original. Beating the water loudly with its tail, it swims in diminishing circles round a shoal of fish, until it has crowded them into a small space, completely at its mercy. In this way it devours enormous numbers of herring, mackerel and pilchard.

The basking shark is a terror to other fish in the North Atlantic, for its remarkably large mouth is designed to seize a vast amount of prey at one gulp. This species reaches a length of 30 feet, and derives its name from its habit of floating with part of its back above the water, as though basking in the sun. Its liver has been known to furnish more than a ton of oil, which is employed in a variety of industries.

Photo: Dr H. Schmidt

The Pennant or Wimple Fish (*Heniochus macrolepidotus*), a boldly-striped denizen of tropical Indian waters

The numerous species of dogfish which swarm in most of the seas of the world are all, strictly speaking, sharks; and so is the fantastic hammer-head, which carries its eyes at the end of projections, or lobes, on either side, so that its head resembles a mason's hammer. Another shark of peculiar shape is the angel-fish, which is flattened like a skate, and has its pectoral fins developed into voluminous wing-like appendages, from which the creature derives its name. But it is a misnomer, for this drab, greyish fish is intensely ugly and has a rank smell of ammonia.

Many of the sharks lay eggs, like the majority of fishes, but other species bring forth their young alive, often to the number of a score or more. In the egg-laying kinds, each egg is enclosed in an exceedingly tough, horny sheath, which in the case of the dogfish comprises the well-known "mermaid's purse" that is found on every beach.

Photo: Otho Webb-Embury Barrier Reef Expeditions

Head of the Sucker Fish, or Remora (*Echeneis naucrates*), showing the sucker plate by means of which this extraordinary fish attaches itself to sharks. It travels about with the shark and lives on scraps left by its involuntary host

Antedon Rosacea, a graceful native of the Mediterranean, with arms like living feathers

As a rule, the teeth of sharks are exceedingly numerous and differ widely in shape, but in all species they are sharp and formidable. They are arranged in rows to form a "pavement," and in many species as the first row of cutting teeth is worn down, the others advance progressively to take its place. The majority of sharks live near the surface of the water, but some species are at home at enormous depths, up to nearly 1,000 fathoms, or well over a mile below the surface. Usually, on being brought up from such abysmal depths, the sudden diminution of pressure kills them instantly.

For inspiring sheer horror and loathing in the popular imagination, the formidable shark is far outrivalled by the octopus, which, however, is actually a far weaker and less dangerous animal. The octopus belongs to the class of Cephalopoda, or "head-footed" creatures, which bear a number of remarkable arms or tentacles growing from the head. The body is enveloped in a muscular sac, or "mantle," and the creature has a short tube through which the sea-water is expelled, after the air has been extracted from it. By squirting the water forcibly through this "funnel" the octopus and his kindred can impel themselves at a rapid rate through the water.

Wonderful Suction Mechanism

In the sinister octopus the arms reach their highest development. There are, of course, eight of them; each arm tapers to a point and is provided on the underside with a double row of round suckers, each of which is operated by a simple yet wonderful piece of mechanism. Once the sucker is in contact with any object, the centre part is retracted like a piston, and a partial vacuum is produced, so that the total grip of each arm, being multiplied with each sucker brought into play, is prodigious; in fact, the whole arm may be torn off before the suckers will yield. In the centre of the octopus, at the part whence the suckers radiate, is placed the powerful, horny, wicked-looking beak, resembling that of a parrot. The octopus has two eyes, large and glistening, and capable of assuming a ferocious expression when the creature is annoyed. Usually the octopus is of a reddish or neutral shade, but some species may be vividly coloured; moreover, it is capable of amazingly rapid changes of colour, according to its surroundings and the varying influence of temper and emotion.

The octopus feeds largely upon crabs and other crustaceans, which, grasping them in

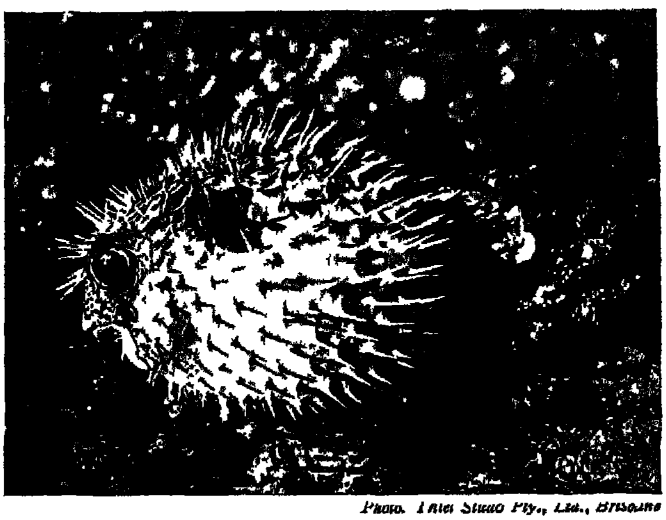
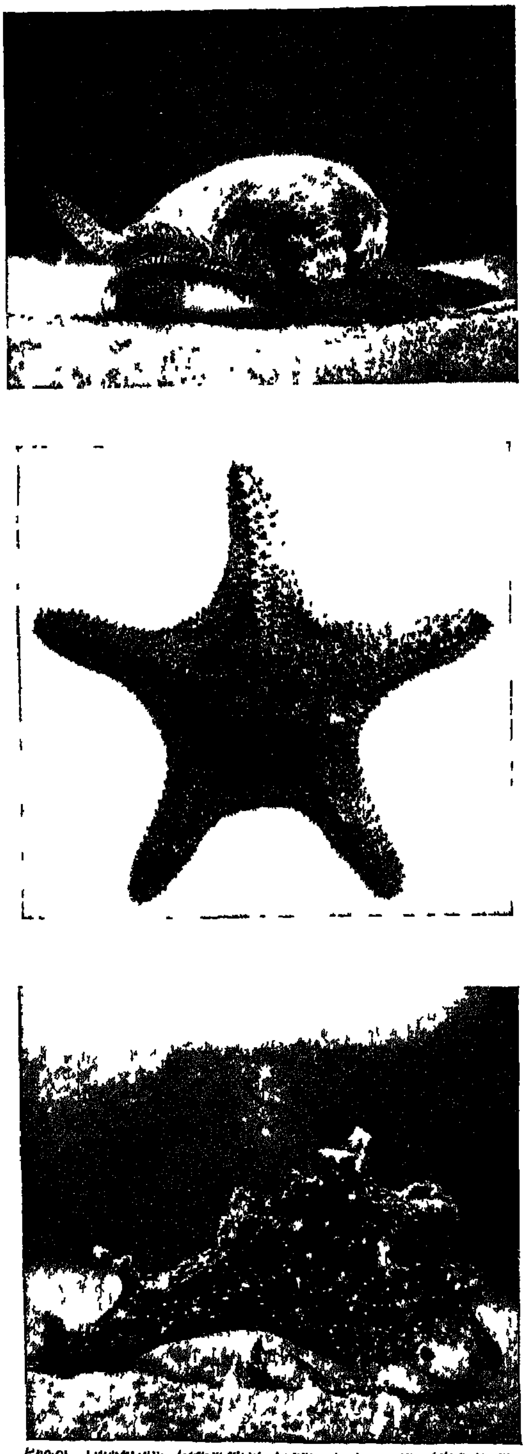


Photo. [illegible] Studio Pty., Ltd., Brisbane

Protected by a thorny armour—the Porcupine Fish which is found in Australian waters



Photos: Queensland Government Tourist Bureau and Otho Webb-Embury Barrier Reef Expeditions

Three curious inhabitants of the sea floor

Top: **Bailer, or Melo Shell (*Melo amphora*), showing shell with mollusc extended while moving under water. *Centre:* Deep-water Sea-star (*Oreaster species*). *Bottom:* Sea Hare**

its relentless arms, it crushes to death with its beak. Its saliva contains a virulent poison which instantly paralyses the victim, and the octopus then devours it at its leisure. Its whereabouts are often betrayed by a heap of broken crab shells lying outside its lair among the rocks.

The common octopus is often met with on the south coast of England, and in 1899 and 1900 the Channel swarmed with them. This species may attain a diameter of 6 feet, though usually it is much smaller. It uses a number of its legs for walking, an operation which it performs head downwards, and it often leaves the sea to hunt for prey among the rock pools. At such times it is said to be able to scramble over the rocks as fast as a man can walk. In Spain and Italy and other countries of the Mediterranean this species is used extensively for food, being considered a great delicacy.

The Enemy of Man

In the warmer seas of the world, especially in the Pacific, the octopus may be a terribly formidable enemy even to man, attaining the enormous diameter of 30 feet, measured from tip to tip of its tentacles. Nightmare stories have been told of this repulsive monster and its silent, remorseless attacks upon sailors and travellers, whom it has dragged resistlessly to destruction in its steely tentacles; and there are reasons for believing that not all such accounts are necessarily the product of an over-facile or over-stimulated imagination.

Related to the octopus are the cuttlefishes and squids. The former have in general a somewhat flattened, squat and oval-shaped body, with a narrow fin running along each side. At one end is the large head, bearing ten strong and active arms, covered with suckers like those of the octopus. Two of these arms are modified in a peculiar way. They are much longer than their fellows, and have club-like tips on which the suckers are congregated. These specialized arms, or tentacles, are ordinarily withdrawn into pouches situated below the cuttlefish's large eyes. The cuttlefish stalks its prey—prawns and other small crustaceans—in a silent and crafty manner, and when it is within striking distance the tentacles are shot out with lightning rapidity to seize the unfortunate victim, which is then clasped tightly by the shorter arms and crushed in the cuttlefish's horny beak.

The cuttlefish carries his shell, or the relics of it, inside his body. It is the exceedingly

light, brittle substance that considerate owners of cage-birds supply to their pets. Our great-grandfathers also used it, in a powdered form, under the name of "pounce," to dry the ink of their voluminous letters.

The Smoke Cloud of the Cuttlefish

The cuttlefish's ordinary method of swimming is by an undulatory movement of its narrow fins, but if alarmed it can retreat backwards at great speed by repeatedly squirting a jet of water through its "funnel." At the same time it pours out an inky fluid—a veritable "smoke cloud"—which obscures the water for some distance and confounds pursuers. It is this inky substance that furnishes the artist's pigment, sepia.

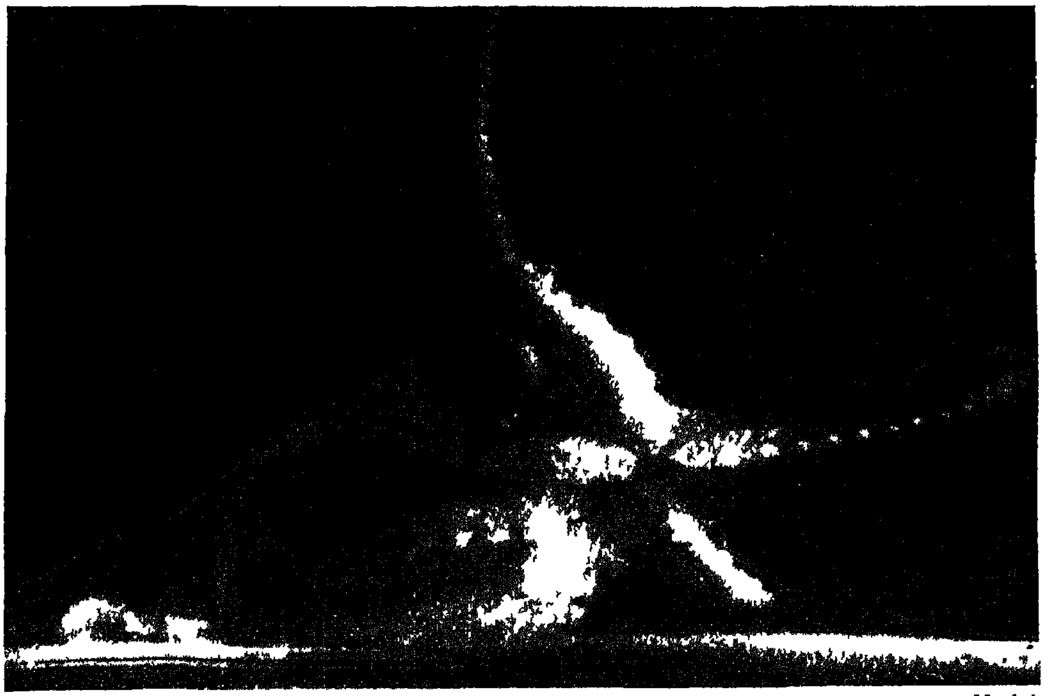
The common cuttlefish is frequently found off the British Isles. In some parts of the world it is used for food, and Italian fishermen in the Mediterranean have a singular method of catching it during the breeding season. A female cuttlefish is towed slowly behind the boat, and the males that follow her are lifted out of the water, one after the other, with a hand-net.

A typical squid, though resembling the cuttlefish fairly closely, has several important points of difference. In general, its body is more elongated and graceful; its fins are large and triangular, and it cannot retract its tentacles so fully as can the cuttlefish. Moreover, the internal shell, or "pen," of the squid is distinctive, being a thin, gristly, yellowish-brown structure, remarkably like a quill pen in appearance.

In some species of squid the suckers bear sharp, horny teeth round their margins, and in others they have been modified entirely into sharp hooks for seizing prey. Other kinds, that live in the depths of the ocean, carry their own lamps with them and are literally blazing with phosphorescent light.

Mention should also be made of the so-called "flying squids," which are credited with leaping clean out of the water for a considerable distance, during which performance they are not infrequently snapped up by sea birds. When their efforts have been aided by a heavy swell on the water, flying squids have been known to jump so high as to land on the decks of passing vessels.

Strangest, perhaps, of all the cephalopods, and certainly the most terrifying, is the giant squid, which may attain a total length of nearly 60 feet. It is the longest of existing invertebrates, or backboneless animals. For centuries this fearsome brute had been occasionally observed by sailors, giving rise to many lurid popular accounts of the



Mondiale

The eight-armed Devil-fish, or Octopus, whose evil reputation is probably worse than the creature deserves

"kraken" and the sea-serpent, which were believed to drag the largest ships to destruction in their monstrous arms; but the generality of scientific men were sceptical of the existence of these giant cephalopods until the latter part of the 19th century, when within a few years a number of specimens incontestably made their appearance in the North Atlantic.

In 1875 a squid with tentacles computed to be 30 feet long appeared off Ireland, and two years later one was caught off Newfoundland that measured 44 feet in total length, of which the arms comprised 33 feet. Larger still was a squid which attacked some fishermen in Conception Bay, Newfoundland, in 1873. Estimated to be 60 feet in total length, it had a beak as big as "a six-gallon keg," and the hinder part of its body was fully 10 feet across. The monster's two longer tentacles were severed with an axe as it was trying to overturn the boat, whereupon it ejected such an immense quantity of ink that the sea was darkened for two or three hundred yards around. A portion of one of the severed tentacles, 19 feet long, was preserved in the museum at St. John's; its original length was estimated at about 35 feet. Fortunately, the horrors of the sea are more than outweighed by its varied wonder and beauty. In the rock pools and coral gardens there are gorgeously coloured polyps and anemones and fishes that dazzle the eye with their myriad tints; and in the cold, gloomy abysses of the deep seas, where perpetual night holds sway, creatures of curious form silently come and go, shimmering with phosphorescence, like ocean liners with all their lights ablaze.

Fish Outrival Butterflies

In their fantastic shape and vivid colouring, many of the fishes of tropical seas outrival the gayest butterflies. Here especially Nature as an artist has shown her master hand. But these gay clothes are not for idle show. Just as the spots of the leopard and the stripes of the zebra make their owners almost inconspicuous to victim and persecutor alike, so do the brilliant colours of fishes, broken up by bars, spots and patches, harmonize perfectly with the vivid hues of the corals, plants and sea anemones among which they spend their life. To such a high art is this

Courtesy of the Australian National Travel Association

Brilliantly coloured fishes of all shapes and sizes abound in the tropical waters of the Great Barrier Reef, Queensland

Photo: Otho Webb Embury Barrier Reef Expeditions

The colouring of certain fishes often serves as an effective protection against enemies. Here is a young File-fish confidently hiding in a sponge

protective coloration developed that some kinds of fishes will remove as evening approaches to a locality toning more readily with their colours in the fading light.

Compared with many of the tropical fishes the charming goldfish of our aquaria seem almost drab and undistinguished. The Paradise fish, for instance, which is kept as a pet in China and Cochin China, is of brilliant gold, banded with red, and has long trailing fins. The angel-fish—not to be confused with the ill-favoured relative of the shark, which goes under the same name—has finny "wings" so long that they extend beyond its tail; it may be orange-red, sky-blue and gold; or simply black and gold; or again, bright orange barred with blue. Of striking form is the Moorish Idol, which hails from the islands of the Pacific; it has a squat, compressed body and a long, beak-like mouth, and its dorsal fin is produced backwards far behind the rest of its body in a long spine. This fish is bright yellow, barred with black.

Some of the wrasses are among the most splendid of all fish. They include the hog-fish of the West Indies, painted a brilliant crimson; the Spanish Lady, in which vivid crimson is richly mingled with gold; and the "pudding-wife," streaked with a lovely blue.

In the coral pools of Hawaii, Samoa and other Pacific islands the wrasses reach the climax of their lavish beauty; all shades of green from olive to emerald, the most heavenly blue, soft rose-red, crimson, purple and the brightest gold mingle in bewildering profusion—not garishly conceived, but merging delicately one into the other, like rare and beautiful tints in a masterpiece of oriental embroidery.

Here is one with an olive-green body, with emerald fins edged with crimson, and a bright red tail, shading off to gold. Underneath, it has bands of purple and lilac, and its head is streaked with the softest rose. Another is spotted all over with black on a golden ground; its head is green, and its fins and tail turquoise blue, fringed with orange.

The parrot-fishes from the Pacific shores are scarcely less gorgeous. Their mouths curiously resemble the beaks of parrots and cockatoos, but their myriad hues put to shame the plumage of even these showy birds. Among the most striking species is one clad

Photo: Dr. H. W. Gr...ande

The vividly marked and coloured Angel-fish, with its trailing fins, is one of the most beautiful of all tropical fishes

entirely in bright, soft green, as though wrought in Chinese jade or exquisite celadon porcelain.

In the same region, too, flourish the most splendid of the gobies and the blennies. A particularly handsome goby has a long, narrow body of vivid green, which abruptly gives way to bright scarlet on fins and tail; while a blenny chosen at random from its glittering fellows is all of celestial blue shading off to golden yellow at the tail.

The beautiful sea anemones are aptly described by their Greek name of Anthozoa, or "flower-animals," and to the uninformed many of them would seem indeed to be exquisite flowers.

The anemone's body comprises chiefly a muscular hollow column which can be firmly attached to rocks by means of a powerful sucker at the base. At the top it is surrounded with a fringe of tentacles, in the centre of which lies the animal's mouth, opening into that inner cavity of the body which forms the stomach. The anemone's method of reproduction is curious; the eggs are fertilized in the body cavity, and the embryos swim about inside their parent until they are ready to be liberated through its mouth into the sea.

How the Anemone Feeds

The anemone uses its numerous tentacles for seizing its prey and cramming it into its mouth: but they also constitute a powerful weapon of offence, for they are crowded with stinging-cells which at the slightest touch release a multitude of slender, spring-like threads bathed with poison. Thus a large sea-anemone can sting as vigorously as a nettle, and the fate of any small sea animal is swiftly sealed once it has come into contact with the flower-like tentacles.

Sea-anemones display an extraordinary variety of form and colour. Some resemble large tufts of coral or bunches of seaweed, others are like tresses of hair, or bundles of writhing snakes; and they run through a whole gamut of colours—blue, crimson, purple, yellow, orange and green. Their

Photo Queensland Government Tourist Bureau

Their endless variety of form and colour make the lovely Sea-anemones indeed the "Flowers of the Sea"

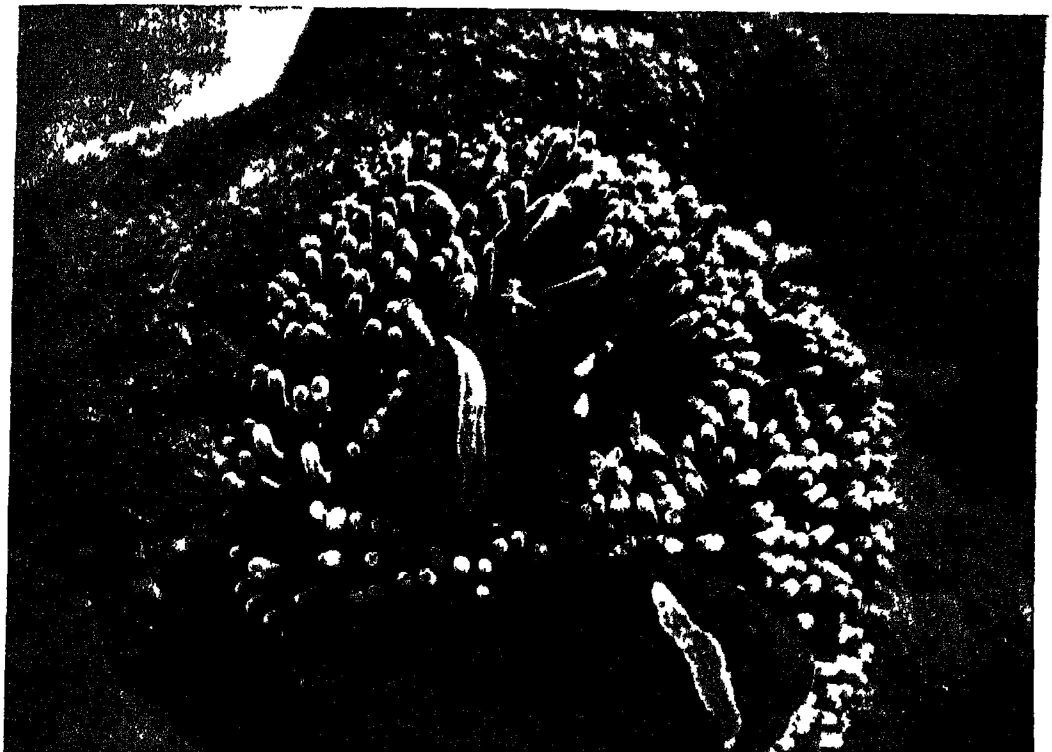


Photo Noel Monkman

The curiously marked Demoiselle Fish emerging from a giant Sea-anemone

Photo Otho Webb Embury Barrier Reef Expeditions

The giant Horseshoe Clam (*Hippopus hippopus*) has gaily painted jaws which form a trap of no mean power. Note the Bêche-de-Mer in the foreground; certain species of these Sea Cucumbers are regarded as great delicacies by the Chinese

habits are equally remarkable. There are certain anemones, for instance, that cling fast to the empty whelk shell inhabited by a hermit crab, being carried about by the latter and partaking of its food; in return, the anemone gives its partner the protection of its stinging cells and probably makes useful contributions to the larder. So indispensable, indeed, are these anemones to some hermit-crabs that on removing periodically to a larger shell they will carefully remove the anemone from their old habitation and replace it securely upon the new one.

More curious still is the association between the anemone and another small crab (*Melia tesselata*) that inhabits tropical seas. This crab perpetually carries a living anemone in each of its two pincers, employing them for catching and killing its prey, which it then removes from their tentacles with its long legs. If deprived of these obliging assistants the *Melia* wanders about, restless and unhappy, until it has obtained other anemones in their place.

The Naturalist's Paradise

On the Great Barrier Reef, off north-east Australia—a veritable paradise for naturalists—are many large and beautiful anemones, some of them more than a foot in diameter, though in the waters of the Far East they may be three times as big. One species on the Barrier Reef is notable as being the home of a gay little orange-striped fish which lives actually in the body cavity of the anemone, passing out at intervals through its mouth to feed and then returning infallibly to the shelter of its living house. In return for its hospitality, it probably acts as a bait to lure prey within reach of the anemone's tentacles. Another species of anemone entertains three such tenants at once—two fishes of different kinds and a prawn.

Enormous Shellfish of the Barrier Reef

Mention of the Great Barrier Reef brings to the mind the giant clam, *Tridacna gigas*, which makes its home among these coral rocks. This is by far the largest of all existing bivalve molluscs—a mammoth among shellfish—its gigantic shell having a span of about a yard, with a weight of nearly a quarter of a ton. But the animal itself, which is edible, weighs only twenty pounds or so. Inside, the shell of Tridacna is pure white, but the outside is vividly coloured to tone in with the bright weeds and corals of the Reef, and it is marked with broad, radiating ridges and flutings. The giant clam is very long-lived, and is said to attain an age of from 60 to 100 years. Though abounding on the Great Barrier Reef, it is not peculiar to it, being found also in Malaya and the islands of the Pacific. The two huge shells are often used to form basins and ornamental fountains, while the ancient inhabitants of the Caroline Islands were wont to fashion them into sharp tools and weapons.

CHAPTER II

HOW MAN WORKS ON THE OCEAN FLOOR

THOUGH there are hundreds of shipwrecks in the course of a year it is scarcely ever worth while spending money or risking lives in an attempt to bring the foundered vessels to the surface. Of course, in the case of a ship which has been battered by a severe storm, and has broken up on a rock-bound coast, the vessel, even if it could be raised, would be worth little, although occasionally its cargo might be of some value. As a general rule, however, only ships which have sunk in shallow waters and which are known not to have been damaged beyond repair receive the attention of salvagers. Exceptions are larger vessels which at the time of disaster were known to have been carrying bullion. To salvage such vessels thousands of pounds are spent: men risk their lives in the effort to locate their exact position in the sea and to bring their precious cargo to the surface.

No man can remain under the water for long if he relies solely on his own natural breathing powers; but the diver with his special suit can not only stay below for considerable periods but is able to move about and work in an upright position. Even were a man able to hold his breath for much longer periods, however, he would not be able to withstand the pressure of the water on his chest, and because of this diving-suits were invented.

Everyone knows that the atmosphere around us exerts a pressure (14·7 lb. to the square inch) on all parts of our body, although we do not notice it. Water is a great deal heavier than air—about 800 times as heavy, in fact—and at approximately

67½ feet below the surface a man has to resist pressure due to a weight of 29 3 lb. on every square inch of his body. At 135 feet the weight on the whole body is about 37 tons, just about nineteen times what he normally experiences In order to be able to resist this extra loading, the diver must have his lungs supplied with air at the same pressure as that exerted by the water around him.

Most of the deaths that occurred in early diving experiments were due not to insufficient air being supplied to the divers but to the enormous pressure of the water around them. It was not until experimenters realized the effect of those pressures that the difficulties were overcome.

There are two kinds of diving-dress: the rubber suit and the "shell" suit. The first practical rubber suit was invented by Augustus Siebe more than a hundred years ago, while the first practical "shell" suit did not make its appearance until 1923.

At work on the sea-bed. A diver forcing his way through the eerie undergrowth of a marine forest. *Top* Cutting through a metal obstruction

The rubber diving-suit is made of rubber and twill and completely covers the diver from head to foot. His head is enclosed in a helmet, and tight rubber cuffs keep the water out of the sleeve holes. Air is pumped into the suit through an inlet valve in the helmet, which latter is also fitted with an outlet valve through which the bad air he breathes out can escape. If the helmet were not provided with the relief valve, the pressure within would get greater and greater. All the upper part of the suit is kept inflated, for it is essential that the air pressure on the diver's chest should be equal to the water pressure outside. The object of having the outlet valve on the helmet is that the diver is free to bend, kneel or lie down while he is carrying on his work. If it were placed elsewhere it might involve certain risks.

This particular valve is made so that it can be adjusted by the diver—for the following reasons. While he is breathing compressed air below the surface of the water, he is forced to inhale very much more air

than his body would require in the ordinary way—that is, he is taking in much more oxygen and much more nitrogen. Under the great pressure he is unable to exhale all the nitrogen and some of this gets into his blood and is carried to the tissues all over the body. If he is under water only for a short period, the effect is not so serious, but the longer he is submerged the greater the amount of nitrogen that gets into his system. When the diver ascends to the surface the nitrogen tries to escape from his body but cannot be reabsorbed quickly enough by the blood; if he rises quickly, it forms in his blood and tissues bubbles which, if they reach the heart, may cause death. Should they form in the spinal cord the diver develops what is called "Diver's Palsy"; and if in the joints, severe and excruciating pains occur, a condition known as "bends."

The diver, therefore, uses the valve to release as much as possible of the excess nitrogen with the air in his diving-suit, but even the opening of this valve will not altogether free him from the dangers just mentioned if he comes to the surface too quickly. When a diver ascends from the depths it is always slowly and in definite stages, each with a halt between, to allow him to get accustomed to the changes in pressure and to give him an opportunity of throwing off the nitrogen absorbed in his body.

To descend is a much easier matter for the diver, for he may go down in one stage. He is very heavily weighted: as a rule he carries 16 lb. of lead on the sole of each boot, a 40 lb. weight on his back and another 40 lb. weight on his chest. This load in no way impairs his movements when he is on the floor of the sea, for he is not conscious of the weight he carries; indeed, his chief care must be not to take long strides, since if he does so his buoyancy will carry him too far. He has no difficulty in working quickly and expertly, and is not unduly hampered in his movements.

The Diver's Telephone

It is not possible here to give a detailed description of the diver's dress, but one other fitting must be mentioned. To the helmet has been added in recent years a connection for a telephone cable, and thus the diver is nowadays not only able to walk, use his hands and work, but also to talk to those above. In the olden days his only means of communication with those at the surface was by means of a rope, and his messages were very limited—restricted almost to signals indicating that he wanted to be pulled up. The telephone, of course, has widened the scope of operations for the diver, for he is able to tell those above exactly what he is doing below and moreover can give and receive advice if anything goes wrong.

The "shell" diving-suit was invented not because the rubber diving-suit had not proved efficient, but because man is for ever striving to improve on his previous records. In this case it is because he desires to go down to greater depths in the ocean than he has ever been before. In the rubber suit he has worked regularly on wrecks and brought up treasure submerged 150 feet under the surface, but now he aspires to carry out routine work at twice that depth; hence the need for a suit which can withstand the greater pressure to which the diver would be subjected at those remoter levels.

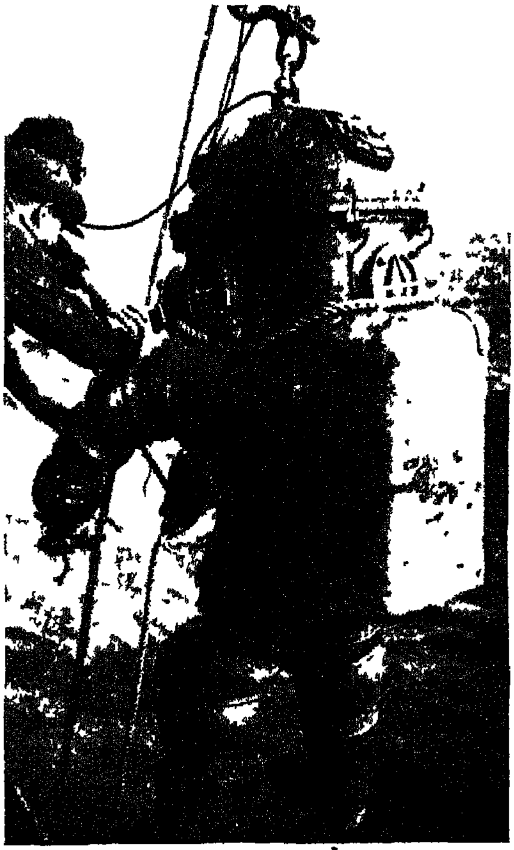
The "Iron Man"

The first workable "iron man" was made by a German firm, Neufeldt & Kuuhe, in 1923. The body and limbs of the diver were encased in steel of circular section with joints that enabled the man to flex his limbs. In the "iron man" suit there are no inlet or outlet pipes, for at the back of the upper part of the shell there is a set of cylinders containing oxygen. The diver breathes the same air over and over again, the exhaled gases passing through a special type of mask which absorbs the carbon dioxide, and the air thus being revitalized with a supply of oxygen from the cylinders. Improvements on the "iron man" are continually being made, but it will hardly change a great deal from its present form.

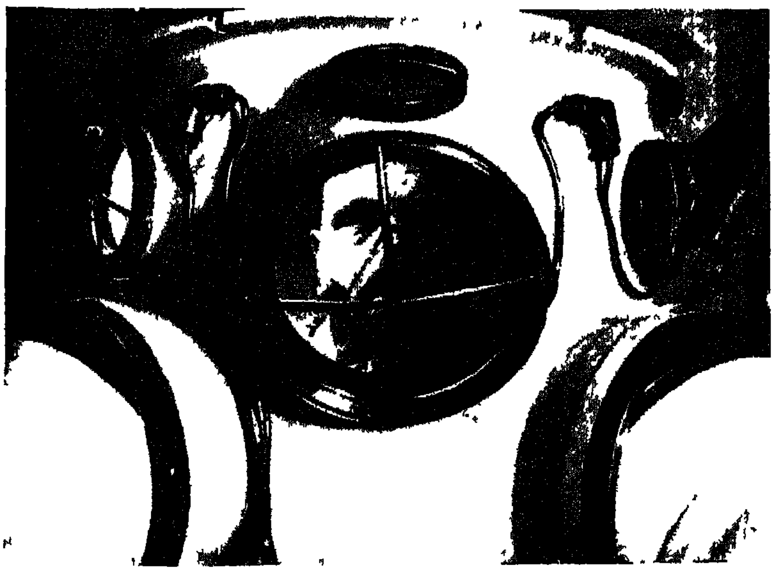
When a diver is to descend he is lowered straight down to his objective by means of a steel cable attached to a ring. There is a telephone cable fixed to the helmet. While the "iron man" has proved itself of great value for certain operations it cannot compete with the rubber diving-suit where actual manual labour is necessary on the floor of the sea. The "rubber man" can do almost anything, but the "iron man" can do very little. Because the diver's fingers are encased in the shell he cannot pick up anything with them; but he has been supplied with mechanical fingers which act on the screw and pinion principle, and with them he is able to perform minor acts of importance. The one big advantage of the "iron man," apart from the fact that the diver can descend to greater depths, is that there is no need for the occupant to spend time adjusting himself to different pressures, since his shell is rigid and he is not affected

by the pressure of the water outside it. He can go up and down very quickly, and in a given time can pay several visits to a wreck where a diver in an ordinary helmeted dress could pay only one. A disadvantage, however, is that the diver in the shell must remain upright; the shell, being attached to a cable from the salvage ship above, is affected by every movement of that vessel. Such movements might lead to the cable fouling some part of the wreck and becoming inextricably caught up in it. How useful the "iron man" has proved, despite these drawbacks, will be told later.

Before passing on to wrecks and the manner of their salvaging, some dangers attending rubber-suit diving should be mentioned. It may occasion surprise that there is little danger from sea-creatures. What the diver fears most is being "blown up," a mishap caused by his outlet valve being shut too tightly. Should the valve not be open sufficiently, his suit becomes too buoyant and instead of rising to the surface slowly he is shot up at a tremendous speed. If he comes up safely he is immediately sent down again in order to "decompress"—decompression is the slow and gradual adjusting of pressure within to pressure outside the suit. Unfortunately he may not arrive on the surface safely; his suit may burst, and if the attendant on board has not been watching carefully and has not pulled in the life-line quickly enough, the rush of water into the suit will cause the diver to sink to the bottom almost as quickly as he came up.



Diver about to descend in the "Iron Man" from S.S. *Orphir* in an endeavour to locate the torpedoed *Lusitania*. The liner was found in 309 feet of water off the Irish coast on October 6, 1935



Close view of the head-piece of a deep-water steel diving-suit. Note the shoulder joints

Another danger to divers is known as "squeezing," and this is far more terrible. A diver may be working on a wreck and possibly through carelessness he may slip and fall, say, five fathoms if the man above has not been holding on to the lifeline and air-pipe. Every square inch of the unfortunate diver's body is immediately subjected to an additional pressure of nearly 15 lb., and the volume of air in the diving-suit is halved. The helmet is rigid and cannot give way,

and in consequence the diver's body is crushed into it with terrific force. If he is not killed he will certainly be terribly injured. The danger of life-line or air-pipe becoming entangled with wreckage or with the hoisting gear is always a possibility but seldom occurs, since both diver and those above who watch over his progress exercise the greatest care.

The most romantic treasure hunt of this century was in connection with the salvaging of the *Egypt*. This vessel was a P. & O. liner which in 1922 was rammed in a fog by the *Seine*, a French steamer, and sank off Cape Finisterre in 71 fathoms of water. A number of passengers and crew was lost, and the vessel took with her to the bottom over a million pounds in gold and silver ingots and coins. The underwriters settled the claims for insurance and gave up all hope of recovering any of it, since no salvage operations had ever been carried out at such a depth. Moreover, they were highly embarrassed and not at all pleased at the number of inventors who came forward with schemes for recovering the bullion on the lost ship. Eventually, in 1923, a consulting engineer, C. P. Sandberg, acting with J. Swinburne, designed a diving-shell to take two men and which it was confidently believed would at least be useful in locating the wreck.

Locating the Egypt

In conjunction with a salvage company the ship *Fritjof* began its efforts to locate the wreck. The finding of a sunken ship is no easy matter, even although the approximate position may be known. However, the people on the *Fritjof*, believing they had located the wreck, marked the spot and returned to harbour to get ready the special apparatus for diving operations. There was some delay in obtaining this, and in the meantime the Societa Ricuperi Marittimi, an Italian firm which had begun to specialize in salvaging operations, contracted with Sandberg and Swinburne to locate the lost ship (1928).

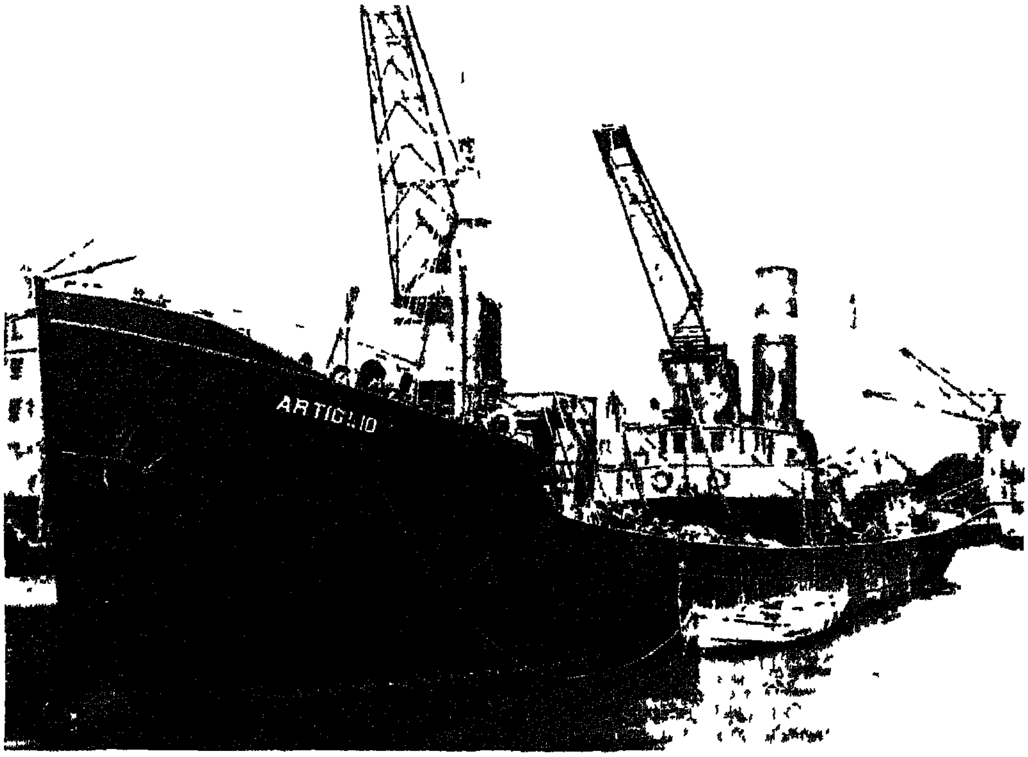
The method adopted was for two salvage vessels to move in a parallel course dragging a heavy steel cable along in the water between them. The ships engaged on the work were the *Artiglio* and the *Rostro*, and they spent a whole season searching for the *Egypt* without success. When the weather was again propitious for their quest the *Artiglio* and the *Rostro* resumed the sweeping operations, and after many disappointments located a sunken vessel. A diver who descended to the floor of the sea in an "iron man" found that the ship was really the *Egypt*. By means of his telephone he directed the *Artiglio* above, and his iron shell was moved until he was near enough to examine the long-sunken liner. Visibility at that depth below the sea was only about six feet, but the diver could discern, among other things, a small hydraulic crane; after a return to port, the salvagers revisited the site of the wreck and by means of a grab succeeded in dragging the crane to the surface, giving final proof that the first stage of the treasure hunt was over.

Recovering Gold from the Egypt

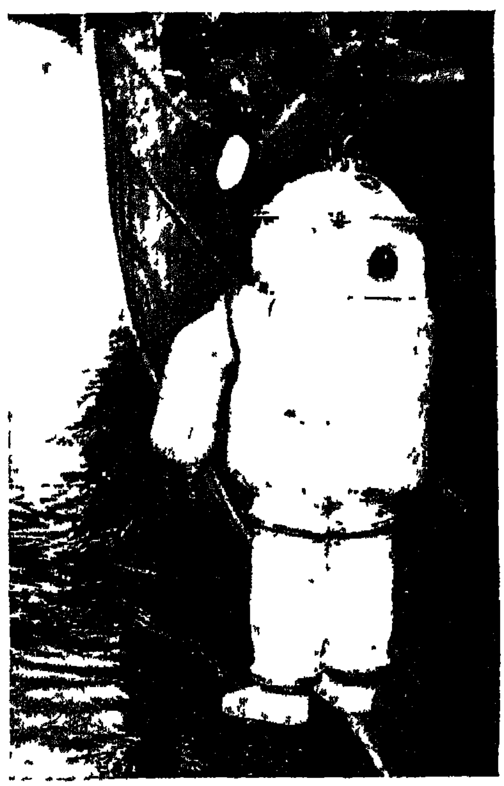
In the operations that now followed, the salvagers on the *Artiglio* gradually began to obtain a clear idea of the position and details of the wreck below them. With grapnels and grabs they tore their way through to the captain's cabin and rescued his safe; but the bullion room, which ran right across the ship, was beneath the main deck, above which were three other decks. Before they could attempt to force their way through, the stormy season had begun and salvage work had to be abandoned for the time.

In December 1930, before work on the liner had resumed, the *Artiglio* met with disaster. She was carrying out the demolition of an American munition ship sunk during the war, and was herself damaged by an explosion, with the loss of three divers who had played a leading part in the work on the *Egypt*. By June 1931, however, salvage operations had been renewed, the diver Raffaelli, who had been fortunate enough to escape the fate of his companions in the disaster above mentioned, being in charge of the work. By the use of bombs placed in position by the crew of the *Artiglio*, who acted on the instructions of the diver below, a passage was blown through the *Egypt* until at last the bullion room was reached; before any of the treasure could be retrieved, bad weather came on and put a term to further work until the spring of 1932. By June of that year, at long last, the tireless Italians were able to let the grab down into the bullion room. It brought up gold, and henceforth success was assured.

The *Lusitania*, torpedoed and sunk off the Old Head of Kinsale in 1915, is the latest quarry of the salvagers. In the autumn of 1935, after three months' search, the vessel was located where she lay, 309 feet deep in the water. On the salvage vessel *Orphir* was the former fourth officer of the *Lusitania*, and



The famous salvage ship *Artiglio* from which the search for the *Egypt's* gold was successfully conducted. *Right:* A diver being lowered into the sea en route for the sunken liner



all accessible information had been garnered about the position of the great liner at the moment when she met her terrible fate. The wreck was discovered by means of a recording echo-sounder. A number of times the *Orphir* was made to traverse the region, and each time the recorder showed the presence of a great wreck standing up some eighty feet from the sea floor. A diver in the "iron man" apparatus descended and found that it was indeed the ill-fated Cunarder that lay there.

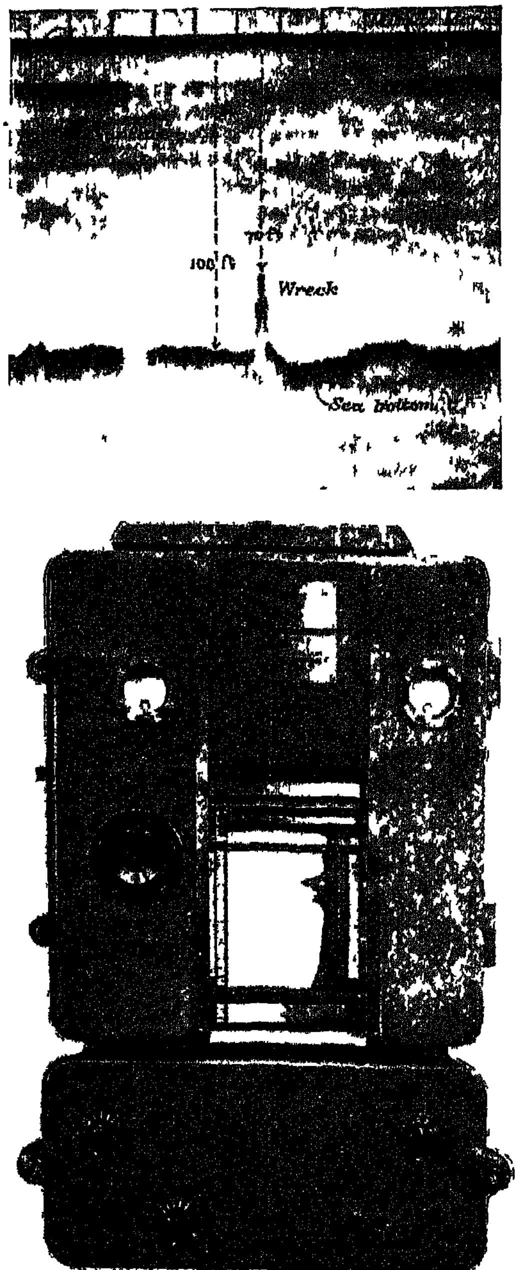
How the Echo-sounder Works

Welded to the bottom of the exploring vessel were two tanks containing the transmitting and receiving apparatus, and the latter was connected electrically to a recording instrument on the bridge. In the engine-room was a motor-driven rotary switch that continually made and broke contact, giving rise to sound impulses that were transmitted downwards to the sea bed. The echo from each impulse was picked up in the receiving apparatus and turned into an electrical impulse. After amplification the received

echo impulse was caused to move a stylus that rested on and marked the chart in the bridge recorder.

The stylus altered its position according to the variation in the time taken by the echo to arrive from the ocean floor. When the ship passed over a hump in the sea bed the echo had a shorter distance to travel, and the mark of the stylus on the chart was nearer the "surface" line. When the vessel had passed beyond the wreck the echo had longer to travel and the stylus descended lower. So the record of the obstacle was shown graphically on the chart

It is not often that an entire vessel is able to be raised, or is of such worth that the feat is attempted, but there are occasions on which an enterprise of this sort is carried out. Probably the most amazing examples are to be found in the raising of the German battleships scuttled in Scapa Flow in 1919. *After the Great War there was a widespread* shortage of raw materials, and metals in particular were in great demand. All manner of war material was bought up, and such things as old warships, guns, tanks, etc., were purchased and broken up so that the materials could be used for industrial purposes



Courtesy of Henry Hughes & Son, Ltd

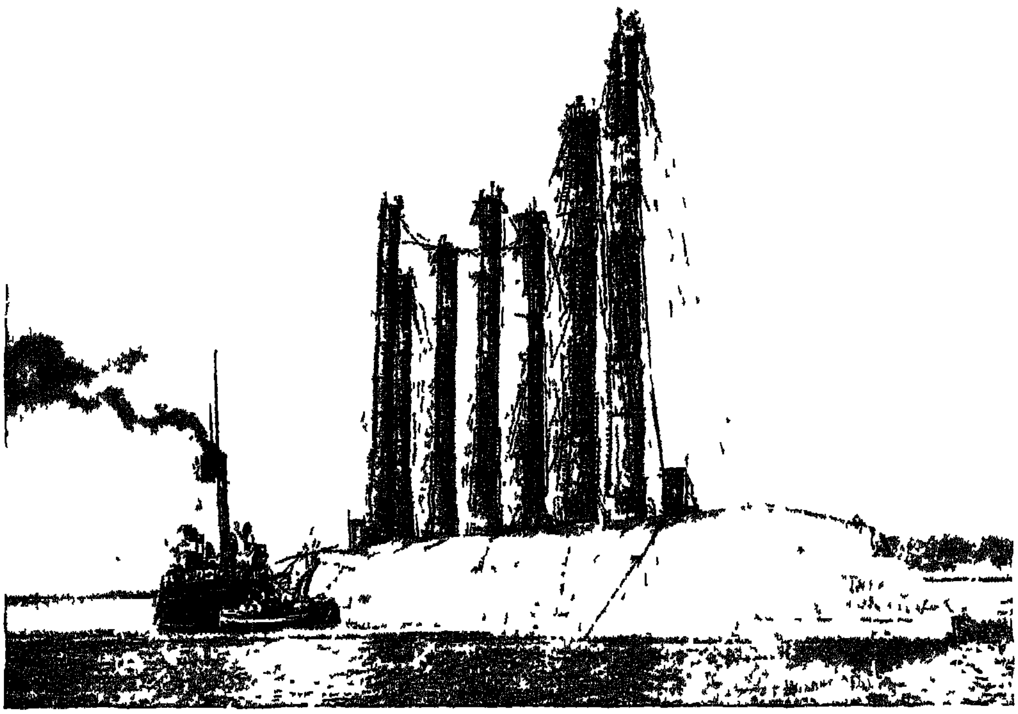
The Hughes Echo-sounding Recorder which, when installed in a ship, greatly facilitates the locating of sunken wrecks and will even record the presence of a large shoal of fish. *Top:* Typical graph, or chart, made by the recorder. It shows the position of a wreck—approximately 38 feet high—between the Inner and Outer *Gabbard Shoals* at the mouth of the River Thames. (The explanatory wording has, of course, been added subsequently)

An Amazing Undertaking

Among iron and steel merchants who were engaged in this trade was E. F. Cox, of Messrs. Cox & Danks, Ltd.; after due consideration he made the Admiralty an offer for the German fleet, in all some thirty ships, lying at the bottom of Scapa Flow. The government accepted his offer and he began to make arrangements for bringing the ships to the surface. Tugs, salvage ships and the necessary machinery for raising the warships were installed near the objective, and included in the plant was a floating dock formerly used for testing submarines. The dock was cut in half, each half being 200 feet long by 80 feet wide, and fitted with sets of 10-ton winches. It was decided that one of the smaller ships, the destroyer V 70, should be the first to be raised; accordingly the half-docks were floated out to the sunken destroyer, and chain and wire cables swept under her. The winches were then put into action and V 70 began to rise. Unfortunately a weak link in one of the chains gave way, throwing additional strain on the other chains, which in turn snapped, so that V 70 sank again to the bottom. Undismayed, another attempt was made, but this time with wire cables flattened where they would have to support the destroyer. This time the latter was raised until its decks were about 2 feet below the surface of the water, when by means of tugs the vessel was towed to the nearby island of Hoy and beached.

One by one the smaller German warships were thus salvaged until at last only *Hindenburg*, *Moltke*, *Seydlitz* and *Kaiser* remained; but these were all much larger vessels, needing a different method of procedure. The first named, after efforts to raise her had failed, was for the time being abandoned; attention was turned to *Moltke*, which was 610 feet long and 86 feet in the beam, clothed for more than three-quarters of her length with 11-inch armour. It was decided now that the comparatively new process of raising vessels by compressed air should be employed. Great difficulty was met with, because *Moltke* was lying with her bows higher than her stern, and when the compressed air was pumped in, some of it would find its way into the bows and the ship would not rise with its keel level. The vessel, it must be noted, was to be raised bottom upwards.

In raising a sunken vessel by means of compressed air it is necessary that divers should first go down into the ship and construct a number of compartments which can be rendered air-tight. Although this was carried out successfully with *Moltke*, further troubles arose because the ship tended to turn on its side. Effort after effort was made to correct the tendency, but not until part of one of the raised destroyers had been lashed to the higher side of the ship's bottom, the ship's bunkers on that side filled with water, and the weight of one of the half-docks allowed to rest on it, was the tendency corrected sufficiently for the vessel to be raised. Even then it was inclined to lift bow foremost, but by releasing some of the air through a valve specially constructed at that point, *Moltke* came up at last on an even keel. Once it was raised, however, trouble was experienced by too much air finding its way into the stern—causing exactly the same trouble as before, only in the reverse direction, so that the stern showed a tendency to rise and the bows to sink. Eventually, however, this difficulty was overcome and the battle-cruiser towed into Rosyth. By similar means the entire fleet was salvaged.



The raising of the scuttled German battleship, the *Koenig Albert*, in Scapa Flow was effected by the use of compressed air. Here the vessel is seen on the surface, keel uppermost, with the 100-foot air locks in position

There are many ways of salvaging ships, and it may be said that no two are dealt with in exactly the same manner. If it is merely the cargo that is to be recovered, less engineering skill is required, since the object then is to open up the wreck so that her freight is exposed and accessible. The raising

of a vessel intended to be put into service again demands quite different treatment.

One method of raising smaller ships in fairly shallow water is to send down water-tight casks which are placed in the hold by divers. This amounts to putting casks of air into the vessel to endow her with buoyancy. A more elaborate method, and one which can be employed for raising larger vessels, is the use of pontoons—water-tight cylinders fitted with inlet and outlet valves. These are floated over the wreck in pairs, and hawsers connecting them are attached by divers to the sunken vessel. If the latter is lying in fairly shallow water affected by the tide, the hawsers are pulled as tightly as possible, then as the tide rises so do the pontoons, and the sunken vessel is lifted from the bottom. The pontoons are then towed inshore as far as possible until the wreck grounds again, and the same process repeated when the tide rises next, until eventually the vessel is uncovered sufficiently at low water for carrying out the necessary repairs. Where there is insufficient tide to raise the ship, a different method is used: the pontoons are sunk by opening their valves and filling them with water. They are then attached to the sunken vessel and the water pumped out of them, giving them buoyancy and causing them to lift the wreck as they rise.

Perils and Profits of Pearl Fishing

The object of pearl fishing is not so much to procure pearls as to obtain the shell of the mother-of-pearl oyster. Though a single pearl may fetch several thousands of pounds in the market, and a ton of shell only £150 or £200, the mother-of-pearl industry is none the less a great deal more reliable as a source of wealth. The majority of divers engaged in pearl fishing are Japanese or Malays, and it is considered that of all the pearls discovered quite half are stolen by the finders themselves.

The headquarters of the industry is Thursday Island, off the coast of Queensland. Small ships sail over the fishing grounds and naked divers dive into the water, gather the shells and bring them aboard. When the store has accumulated it is transferred to a larger vessel, which when it has a sufficiently large load returns to port. To a large extent naked diving, however, is being superseded—mainly owing to the Australian government withdrawing the licences of the Japanese divers. Owing to the great depths at which the pearl shells must be sought, the employment of the rubber-suited diver is a costly business, as he can stay down only for five minutes or so and yet, because of the necessity of slow decompression, it takes nearly an hour to lower him and bring him up again. In shallower waters men are able, of course, to stay down much longer, and in the course of that time they gather as many shells as they can and place them in a net bag which is later drawn up to the surface.

Primitive Methods used in Sponge Fishing

Although the rubber-clad and helmeted diver is employed in sponge fisheries, more primitive methods are still in use, particularly in the Mediterranean industry. Here boats are propelled over the places where sponges are known to grow, and a naked diver enters the water and gathers as many as he can before rising again to the surface. This method is not so simple as it reads. What actually happens is this: the diver stands in an upright position facing the prow of the boat with his arms extended straight above his head, in his hands is a large flat stone attached to a long rope which is coiled up behind his heels; the rope passes through a ring which is connected by a short chain to another ring round the diver's wrist; across the man's back is slung a net bag for receiving the sponges as he collects them. The man dives into the water, the stone aiding him in his effort to reach the spot where sponges have been sighted. As the stone lands on the floor of the sea the diver releases his hold of it; his arm with its ring slips up the rope, and he is able to walk or bend at will. With the stone as a centre point he collects all the sponges round it, drops them into his net, and then comes to the surface, the stone being hauled aboard after him. This method is used where the floor of the sea is uneven and set with reefs, and where diving dresses are impracticable owing to the danger of air-pipes becoming fouled or cut through by the sharp-edged rocks.

One other kind of diving apparatus used in the sponge fisheries is worth recording. It consists of a belt strapped round the waist, from which is suspended an air-bag connected at its lower end by an air-pipe to a pump on the boat's deck. A connection on the top of the bag is joined to a flexible tube which is carried up the diver's back to a right-angle bend, and another piece of flexible tubing passes round one side of his neck to a mouthpiece which is clenched firmly between the teeth and lips by the diver. A neck-strap supports the flexible tubing and

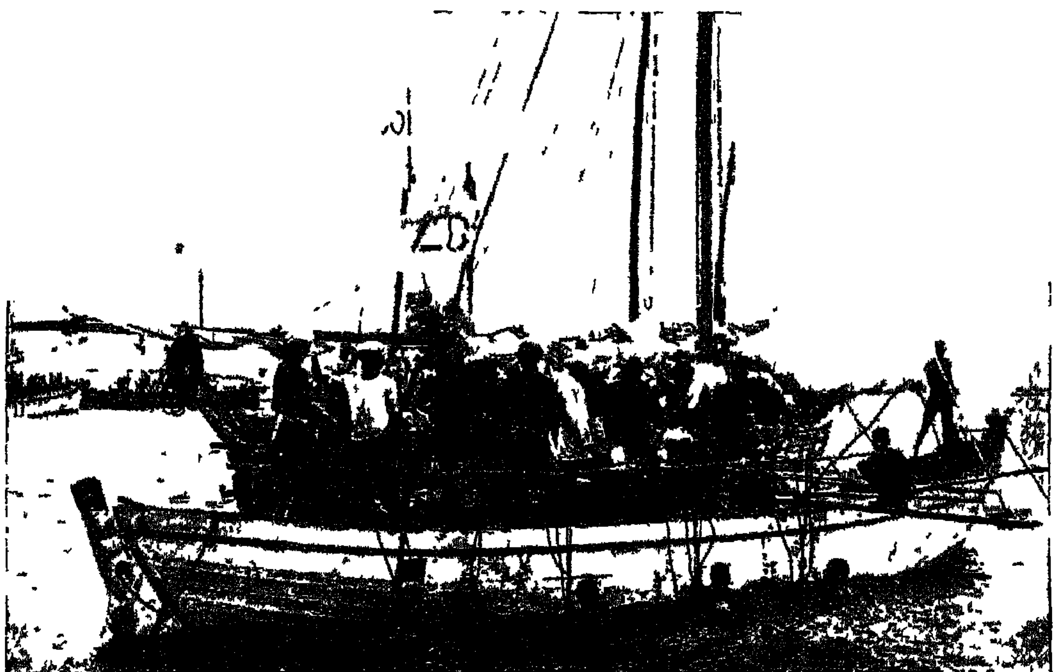
mouthpiece. This apparatus makes it possible for naked divers to remain below the water surface for five or ten minutes without any harm and without the need of decompression.

One of the most wonderful achievements of man in his activities beneath the surface of the sea is the submarine cable. Sending a cablegram to America has become so commonplace that few ever consider how the first submarine cable came to be laid or how such arteries of communication are kept in repair.

The first submarine telegraphic cables of any practical use were laid between England and the European continent in the middle of the 19th century; but few could have thought that it would be possible to lay one across the Atlantic ocean, although it had been established by soundings that between Ireland and Newfoundland there was a natural plateau on the ocean floor that would make an ideal bed for a cable. Scientists and inventors for the most part considered the suggestion quite impracticable since no ship, they said, could take the length of cable required even if such a cable could be made. Moreover, even were both these difficulties overcome, the stormy weather would make it impossible to carry out the work. Eventually, however, Cyrus Field, an American business man, consulted Morse, the inventor of the telegraphic code, and satisfied himself that the project was not so impossible as it seemed. He travelled over to England and there got in touch with Charles Bright, who had already laid several other submarine cables which had proved successful. The result of this meeting was that a start was made in 1857 to lay a cable from Valentia in Ireland to Heart's Content in Newfoundland, a distance of 1,640 nautical miles.

Two warships, the *Agamemnon* of Britain and the *Niagara* of the U.S.A., with one or two smaller vessels, were commissioned to undertake the task. The American vessel was to take the one half of the cable and pay it out into the ocean; and about half-way across it was to be spliced to the other half of the cable, lying in the hold of the *Agamemnon*, which would then continue the process onward to Newfoundland. Nearly 400 miles out of Valentia the cable snapped and the cable ships had to return and lie up for the winter. The following summer the same vessels made another attempt; this time the cable was spliced in mid-Atlantic, and while one ship paid it out on its return to England the other paid it out on its way to Newfoundland. Again the cable broke, and both ships returned to Queenstown; but within a week a third attempt had been begun and this time it met with success.

The feasibility of the project was proved,


E.N.A.

Native pearl divers at work in the Gulf of Manaar, Ceylon

and although this first cable failed to function after three months, owing to technical difficulties that had hardly been foreseen, there was no question of abandoning the venture. In 1865, the *Great Eastern*, after one further mishap, laid a cable which functioned satisfactorily and endured. Since that time other cables have been laid, and between Europe and North America there are now twenty-one such arteries of communication through which messages pass continuously, day and night.

roughly whereabouts the defect may lie. Delicate instruments measure the electrical resistance from each shore end of the line. Over another cable the engineers check data and compare calculated results. The fault is located, bearings plotted on a chart, and the cable ship makes for that particular spot. It passes over the cable track at right angles and, by means of grapnels dragged over the floor of the sea, is able to pull up the cable for inspection. The cable is cut and a message sent in both directions.

Courtesy of the G.P.O.

On board a cable-ship: watching the pressure gauge, which must be kept at about 18 cwts.

Special cable ships are constantly engaged in the repair and maintenance of the telegraph and telephone channels between this and other countries. The Post Office and the private cable companies keep ships in port ready to fare out to any spot where a breakdown may occur. Every great storm may be a potential source of danger to the cables, and these vital arteries must be repaired at utmost speed, for along them flows the life blood of commerce and industry.

The ships are built for the work and have at their bow and stern large drums over which the cables pass when they are being paid out or drawn in. Should a cable cease to function properly it is possible to tell

The defective side of the cable will fail to yield a response, and the sound end is thereupon fixed to a buoy while the ship winds in the defective section, testing it from time to time. Once contact between ship and shore is again established over this part of the cable, the defective length is cut away and a new section spliced on to it. The cable ship then proceeds to the buoy marking the other portion of the cable and joins the new piece to the latter. This done the vessel proceeds with her routine work, or returns to port ready for another emergency call. Such is the work of the cable ships in maintaining rapid communication between north and south and east and west.

CHAPTER III

FROZEN SEAS OF NORTH AND SOUTH

BUT hee holding nothing so ignominious and reprochfull, as inconstancie and levitie of minde, and perswading himselfe that a man of valour coulde not commit a more dishonourable part then for feare of danger to avoyde and shunne great attempts, was nothing at all changed or discouraged, remaining stedfast and immutable in his first resolution: determining either to bring that to passe which was intended, or els to die the death."

Thus Richard Hakluyt, in his immortal "Voyages," describes with words that read almost like an epitaph, the dauntless spirit that animated Master Richard Chancellor in his perilous voyage through the uncharted Arctic seas towards the land of Cathay, in the year of our Lord 1553; and it is the same spirit of grim courage and determination that has opened up the frozen seas of either Pole to the eyes of men.

Setting aside curiosity and the thirst for adventure, the original motive leading to the exploration of the Arctic was a material one enough; it was a knowledge of the great profits that could be made in foreign trade by the opening of a route through the seas north of Russia and Siberia to Cathay, or China, and the opulent Indies. This had been the cherished dream of seamen and merchant-adventurers since the end of the 15th century; but by the year 1879, when the North-east Passage was finally made by Nordenskiöld, this arduous route had become a matter of only scientific and geographical importance.

The seamen of Tudor England failed to find the North-east Passage, but they failed brilliantly, and out of their brave endeavours, and also from their attempts upon a corresponding passage to the west, sprang the beginnings of most of our present knowledge of the Arctic seas.

The penetration of the Antarctic sprang from a somewhat similar motive; though in this case it was much tardier. From the 16th century to the time of Captain Cook many people had a strong belief in the existence of a huge "southern continent," or "Third World," which was not only habitable, but mild in climate and richly fertile. In 1772–75 Captain Cook made his memor-

able voyages in the Antarctic seas and crushed the hopes of prospectors by showing that this region was little else but a barren mass of ice. Other explorers followed Cook, and their labours, together with those of many nameless whalers and sealers of all nations, laid the foundation of our knowledge of the Antarctic.

Nowadays, even the most stay-at-home person is able to gain a good idea of the

ice when he designed the *Fram*, a vessel of enormous strength and with a hull so modelled as to rise above the ice sheet as soon as it felt the grinding jaws of the pack. The *Fram* rode in this fashion upon the drifting ice continuously for nearly three years, passing right over the North Polar basin from one side to the other and often with a depth of water below her, underneath the thin crust of ice, of more than two miles.

This floating, drifting ice covers the greater part of the Arctic sea, and has an area of nearly two-and-a-half million square miles. Melting where it meets warm currents, being re-formed and reinforced by the ice from glaciers and frozen rivers, it moves slowly but ceaselessly from east to west, to disintegrate in warmer latitudes.

When floes of ice meet, a terrific pressure arises, which usually results in the ice
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In the Antarctic are found the mightiest glaciers in the world. The South Polar region, though it may hold comparatively a greater mass of solid land, as against the floating ice-cap that surrounds the North Pole, yet has more than five million square miles of ice. Some of its glacier tongues may project thirty miles into the sea, as that of the Drygalski Glacier is reported to do. The great size of many of these glacier bergs

Photos: the late H. G. Ponting

Beautiful effects of morning and evening light on the great ice packs of the Antarctic seas

can be realized from the fact that when in the autumn of 1911 a huge glacier tongue in Erebus Bay, Ross Island, broke off at the end, the detached portion, which drifted away to sea, was more than two miles in length.

The formation of a glacier iceberg occurs in exactly the same manner wherever it takes place. The ice-river thrusts its great nose farther and farther into the sea and usually much deeper than the level at which the ice, if free, would float. A terrific upward pressure is thus exerted upon the tongue of ice, which eventually breaks off near the end with a heavy splash and a roar as of thunder. This the Greenlanders term the "calving" of the glacier. Having found its proper level in the water, the new iceberg floats away majestically upon the current, while the glacier prepares after months or years to put forth another iceberg.

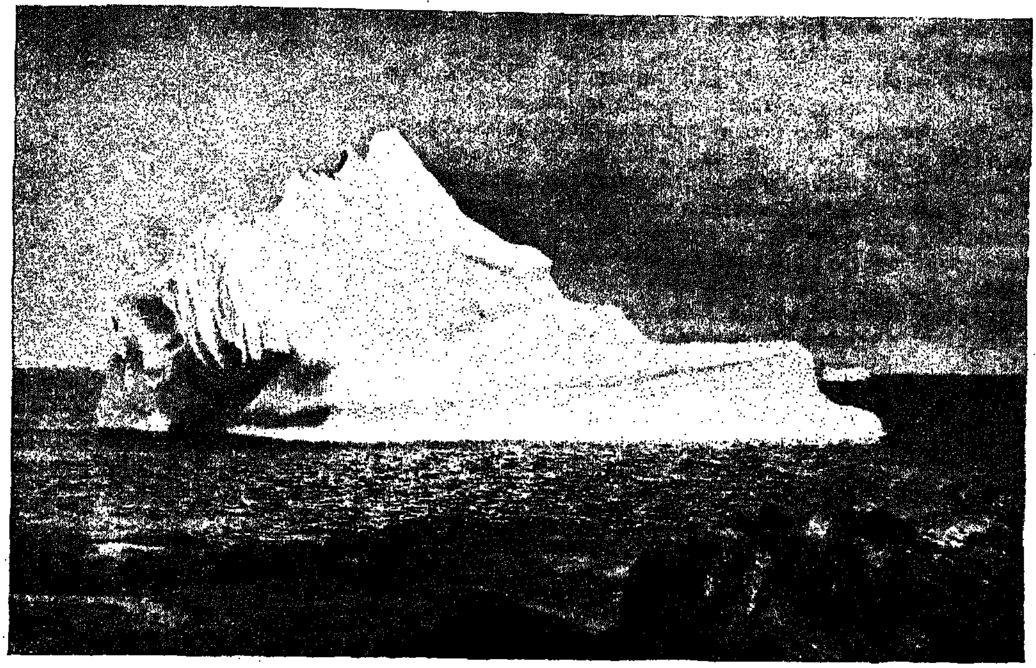
A large iceberg is a wonderful, if terrifying, spectacle. In the Southern Polar seas they may rise, though exceptionally, to 700 feet; and yet it must be borne in mind that only about one-ninth of their mass is ever seen above the water, and usually it is the submerged and unseen but projecting portion that is such a serious menace to shipping.

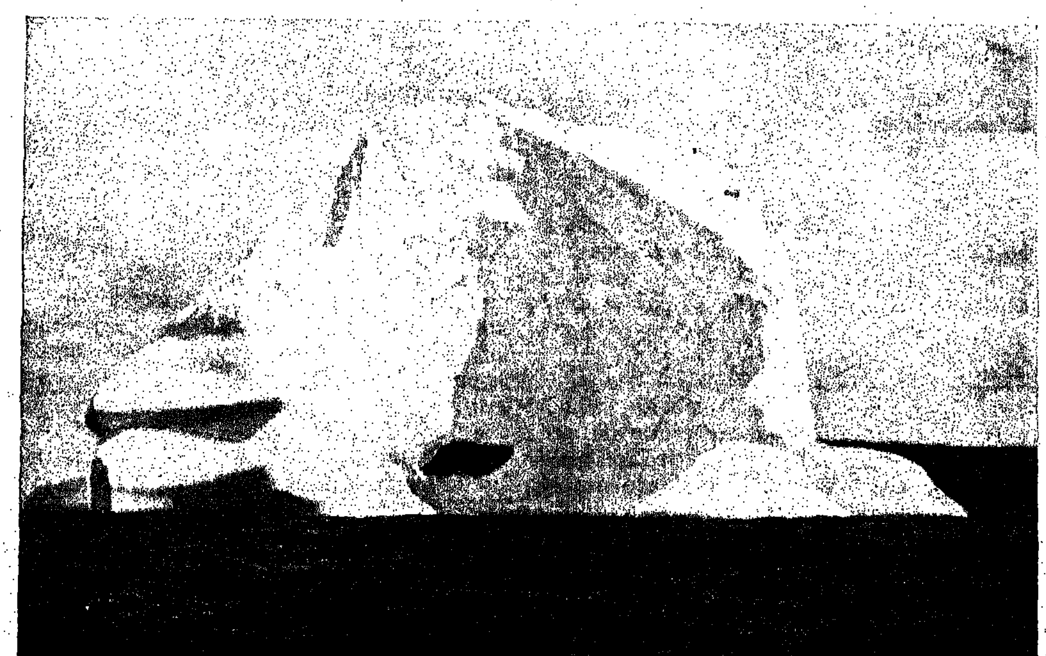
When an iceberg sails into warmer water there is a rapid melting of the ice at the base; the centre of gravity is displaced and the berg—weighing probably many thousands of tons—turns turtle with tremendous violence, throwing lofty columns of water into the air. All icebergs disintegrate in time, as they encounter warmer seas—though in the Antarctic they may have a life of several decades—and they are continually throwing down upon the sea-bottom the rocks and detritus gathered up, perhaps hundreds of miles away, by the glacier that gave them birth. But long before they come to complete destruction, large portions of them are perpetually breaking away, with a splintering crash that echoes among the peaks and pinnacles of the berg and can be heard far and wide over the water.

Carved into caves, crevasses, mountain tops and gullies, with cascades of water streaming from their airy pinnacles and the sunlight gleaming on their great flanks—snowy white on the ridges, deep blue in the shadows—icebergs provide such a perfect example of Nature's magnificence that it is

Courtesy of F. A. Brockhaus, Leipzig

The shores of Kamarujuk Fjord, on the west coast of Greenland. *(From "Alfred Wegener's Last Greenland Expedition")*





H. J. Shepstone

Icebergs often take remarkable shapes of which these are typical examples. Note the "window" in the lower one

easy to overlook their more sinister aspect. Yet on some shipping routes they are a potential danger that never ceases, demanding an unremitting watch and an annual expenditure of thousands of pounds in order that travellers on the ocean highways may come and go in peace. Though it happened as long ago as 1912, few have forgotten the calamity of the *Titanic*, when an iceberg that had drifted below its normal latitude caused the loss of over 1,500 lives in the North Atlantic.

In 1913, prompted by the *Titanic* disaster, the leading nations of the world united in taking active steps to obviate the iceberg peril as far as possible. The result was the formation of the International Ice Patrol, comprising a fleet of sloops belonging to and manned by the United States Coastguard Service and subsidized by all those nations with an extensive traffic in the North Atlantic. The personnel of the Ice Patrol is drawn from the finest and fittest types of officers and men, and all the assistance that science can offer is enlisted for the detection and destruction of dangerous masses of ice.

In foggy weather the temperature of the sea is frequently taken, any abnormal drop indicating the neighbourhood of ice, large masses of which chill the water for a considerable distance; and there are also automatic alarms which loudly call attention to a decrease of temperature. The ships of the Ice Patrol are in constant touch by wireless with all vessels in their vicinity, reporting the exact latitude and longitude of the bergs, with their course, speed and other details. The most dangerous icebergs are repeatedly shattered with high explosives until they are so reduced in size as to offer little menace.

Tabular Icebergs of the Antarctic

The so-called "tabular" icebergs, which are so characteristic of the Antarctic and are not found so frequently in the Far North, do not originate from glaciers, but are simply huge chunks broken from the floating tablelands, or "shelf-ice," that surround the Antarctic coasts. The great Ross Barrier is the largest known example of shelf-ice: it is a vast floating tableland that stretches along the shore for 600 miles, with a breadth of 300 miles, presenting to the sea an unbroken lofty wall of ice in places 150 feet in height. This colossal slab of ice, in extent more spacious than the North Sea, and with an average thickness of 400 feet, floats gently upon the water, drifting slowly along the coast at the rate of about one mile in a year. Another mighty example of shelf-ice is the Shackleton Shelf, discovered by Sir Douglas Mawson, which extends over a space estimated to measure about 170 miles in length and 150 miles in width.

Shelf-ice is almost entirely composed of sea ice, heaped up into a solid cake and covered with the compacted snows of centuries. From the water it has all the appearance of a glittering white landscape, carved up into bays, peaks, crevasses, deep caverns and unassailable bluffs, just like a coast of rock. This barrier, as we have seen, gives birth to tabular icebergs, which are by far the greatest of all, though they are of little danger to shipping, since they seldom drift so far north as the regular routes. Sir Douglas Mawson reported a tabular iceberg forty miles in length, with a height of 150 feet, and there is reason to believe that this size may be far exceeded; the weight of these giants must be millions of tons. So numerous are icebergs—both glacial and tabular—in the Antarctic that thousands have been sighted from a single ship in the course of a day.

How Man Navigates the Frozen Seas

When man encounters ice in its own vast realms, round the Poles of the earth, he can do little to subdue it; he can only humour it, keep it at arm's length and be forever on his guard. But where its hold is weaker, it can be conquered with comparative ease—crushed, broken in fragments and flung aside by the iron nose of the icebreaker. The Russians, to whom it is of vital necessity to free their ice-bound rivers and northern ports, have been the chief pioneers in the development of the ice-breaker. The earliest ice-breakers were heavy wooden vessels, strongly braced with iron. The first practical iron vessel of this type, steam-driven, was the *Eisbrecher I*, launched in 1871. She was followed by the celebrated *Yermak*, designed by Admiral Makaroff of the Russian Navy, and built in 1898. This was a large boat, being 320 feet in length and very broad in the beam. She had a displacement of 8,000 tons, and her engines were capable of 8,000 horse power. The *Yermak* continued in active service for many years, though other ice-breakers were built exceeding her in size and power.

In 1928, when the airship *Italia* was wrecked in the Arctic wastes, it was the Soviet ice-breaker *Krassin*, summoned from hundreds of miles away by wireless, that

brought succour to the eight survivors, after forcing her way for weeks, slowly and surely, through the floating ice. The *Krassin* was a powerful vessel, capable of 10,500 horse power and carrying 3,000 tons of coal in her bunkers.

The majority of modern ice-breakers are designed on a very simple principle: the hull, besides being enormously strong to resist the thrust of the ice, has a gradual upward slope towards the bows, so that the ship's nose can be run up on to the ice sheet in front of her, her great weight thus breaking large pieces from it in succession

Members of the crew of a sailing schooner preparing to blast a passage through pack-ice in the Bering Sea

On the Volga and on Lake Baikal, in Siberia, where for months the water is frozen to a depth of several feet, ice-breakers have been combined with train-ferries, the ice being split and forced aside by the vessel's sharp stern-post and heavy bows These ferries play an important part in the connections of the Trans-Siberian railway.

Ice-breaking vessels have played an indispensable rôle, also, in one of the most important enterprises of modern times—the opening-up to commerce of the historic North-east Passage. The Russians have always been interested in this potential route along their ice-bound northern coast, though the pioneer work of reconnaissance was left to the adventurers of other nations, including a succession of gallant Englishmen. In 1648, Simon Dezhneff, a Cossack, made an attempt upon the passage from the Bering Strait end; and in 1738 a party of Russians, setting out from Archangel, reached the mouths of the Ob and the Yenisei. Five years later, Lieutenant Chelyuskin made a sledge journey round the most northerly point of Siberia—the cape which now bears his name. Many other Russian attempts followed, in addition to those of other nations, resulting in a collection of geographical and scientific facts of immense value

To-day the Soviet government is putting these marvellous results to practical account. Convoys of boats, led through the heavy floes by powerful ice-breakers (prominent among which is the British-built triple-screw *Lenin*), thread their way along the Siberian coast, in the track followed by Nordenskiold in 1878, and many hundreds of miles farther than the point where Sir Hugh Willoughby, the companion of Richard Chancelor, perished in 1553 Aided by wireless, aeroplanes and the all-important ice-breakers, they bear hundreds of seasonal workers to the Ob and the Yenisei, well within the Arctic Circle, where Russia is finding a new source of wealth in the inexhaustible timber and fisheries of Siberia.

Animals that Dwell in Polar Lands

There is little diversity to be found among the wild life of the more desolate parts of either Pole, and the limited kinds of plants

and animals that do exist here have been peculiarly modified, as might be expected, to enable them to endure the severe conditions of temperature. Even seaweeds and algæ cannot flourish in perpetually ice-covered sea, though in the more open parts of the Arctic seas, where the water is warmer and the sunlight unrestricted by fogs, both plant and animal life are plentiful, and here are to be found the main feeding-grounds of the great Greenland right whales. Trees are non-existent in both Arctic and Antarctic, though fossil trees have been found in the Far North, indicating a very different climate in the remote past from that experienced to-day. The characteristic vegetation consists of mosses, lichens and fungi—all low forms of plant life—though in the Arctic long grass may abound, save on the ice-fields. Some of the mosses grow in great tufts twelve inches or more in thickness, while many of the Arctic flowers are bright and beautiful.

Animals that dwell in Polar Lands

Large animals are abundant in the Arctic, though their variety is restricted. The Greenland whale, the white whale (which sometimes falls a prey to prowling Polar bears), and the narwhal range as far as the extreme limit of open water. Seals are numerous and diverse; while in the Pribyloff Islands and Bering Strait are found the great northern sea-lions and sea-bears, some of which may measure 10 feet in length.

Giant Carnivores of the Arctic

Here, too, the exceedingly clumsy but very likeable walrus is found at home, it does not occur in the Antarctic. The walrus is one of the largest of all carnivores, the adult males reaching a length of from 10 to 11 feet, or even more, with an extreme weight of well over a ton. It is allied to the seals, to which animals it has a general resemblance, though it can readily be distinguished by its enormously developed canine teeth—the well-known "tusks." In an adult male these may grow as long as eighteen inches, but they do not begin to appear until the walrus is at least a year old. They form a very powerful defensive weapon, which often is more than a match for the walrus's chief enemy, the Polar bear. Their more peaceful function is for digging out of the sand the clams and other molluscs on which the walrus largely feeds, after cracking their stony shells in his powerful jaws; and these great teeth are said to be used also for getting a good purchase on the slippery ground, when their unwieldy owner hauls himself about the rocks and ice-floes.

Like the true seals, as distinct from sea-lions and sea-bears, the walrus has no trace of an external ear, beyond a small hole in the

Bergs and pack-ice are not the only dangers attendant on navigation of the Arctic seas. In the warmer weather, mirages sometimes occur which distort landmarks and add to the sailors' difficulties. Here is one seen off the entrance to Hudson Strait

Photo. the late H. G Ponting
A Weddell seal with its young thoroughly enjoys being photographed: the lighter side of Antarctic exploration

skull. Its eyes are small and perpetually bloodshot, adding to the truculence of its appearance. Its body is covered with tawny yellow hair, which may fall off in old age; and from its muzzle grow many coarse, stiff whiskers, as thick as quills, which act as extremely sensitive organs of touch. The walrus can give voice to a very loud and terrifying roar, audible at great distances.

The walrus produces one or two young ones at birth, and the parents are very affectionate and solicitous towards their offspring, which are carried through the water on the back of their mother. When, as not infrequently happens, the murderous appetite of the Polar bear deprives them of their young, the ferocity of the old walruses is terrible to see, and they then display an almost human ingenuity in their endeavours to force or lure the offender into the open water, where they are more than a match for him.

The Walrus Posts Sentinels

Walruses often foregather in large herds, sometimes on drifting ice-floes many miles from land. It is a curious fact, first reported by Captain Cook, that no matter how somnolent the whole herd may appear, there are always some sentinels with a weather-eye open for danger, who at the first sign of alarm awaken their neighbours with unceremonious prods of their tusks. This movement is repeated through the entire line, until all are watchful and alert. When alarmed or annoyed the walrus is said to draw back its lips, so as fully to expose its great tusks, and to make a loud chattering noise with its teeth.

Habits of the Great White Bear

Like the walrus, the Polar bear also is peculiar to the Arctic Circle, never occurring naturally in the south. With its thick, creamy white coat, its great size—seven feet or more from the nose to the root of the tail—and its alert and comparatively small head, it is one of the most handsome of all animals The Polar bear's nose and tongue and the inside of its mouth are jet black, as also are the soles of its feet; and the latter are provided with short, firm hairs which enable their owner to get a secure grip on the slippery ice.

The Polar bear is a powerful swimmer, and it dives with elegance and aplomb. It is almost as at home in the water as it is on land, and the females have often been observed giving swimming lessons to their cubs, ducking them repeatedly and often belabouring them severely during the process. Until they are proficient enough to swim entirely unaided, the young bears are in the habit of holding their mother's heavy tail in their mouths, and in this way are towed along behind her.

These great white bears are bold and adventurous travellers. They have been observed on icebergs and drifting floes far away from land and quite alone on the desolate sea. William Scoresby, the traveller and naturalist, once saw a Polar bear calmly cruising through the open sea on a detached sheet of ice, 200 miles from the nearest land. It seems most feasible that these bears chance to be on the ice-edge or the nose of a glacier when it becomes detached from *terra firma* and is borne seaward, and so become unwilling travellers. At all events, they have been known to come ashore as far south as the coast of Iceland, where, being very hungry after their voyage, they have proceeded to make free with the flocks and herds of their hosts. But it also seems likely that these bears are capable of swimming astonishing distances on their own account, for they have been seen forging through the open sea as much as 40 miles from land, with no floating ice within sight. The motive that prompts these daring expeditions—unless it be a sort of wanderlust—seems to be quite obscure.

On land the white bear is very active and can cover the treacherous ground with great swiftness, so that it is a dangerous opponent

Photo: Seidenstücker

The Polar bear is a strong swimmer and is equally happy in the water and on the ice and snow

Photo: the late H. G. Ponting

Among the sparse fauna of the Polar Regions is the skua, a species of Gull. This week-old chick was found with the eggs in a nest in the Antarctic

to encounter. It seems, also, to be highly intelligent, and explorers have told remarkable stories of its manifold feints and subterfuges when engaged in stalking a man—how it will pause and affect to retreat or to be interested in something entirely different, at the same time attempting to cut off its quarry from safety.

Equally ingenious is its method of trapping seals, which observers have repeatedly vouched for. Marking down from afar a seal that is sleeping or resting by the water's edge, the bear approaches it unseen and with noiseless tread, then diving swiftly into the water near by, comes up just in front of its prey. The seal's retreat by water is thus cut off, and since it can only move slowly on land, its fate is a foregone conclusion.

The Polar bear respects the powerful walrus as the only wild enemy in the entire Arctic waste who can engage with him on equal terms; and, avoiding close quarters, it is said he adopts the cunning practice of rolling heavy boulders from above on to the walrus and so crushing him to death.

Polar bears live chiefly upon seals, fish, birds or any live thing that comes to hand, but they will just as readily devour seaweed, grass and berries, or even the rotting carcasses of whales and the tents, boots and medical stores of explorers. They are themselves hunted and eaten by the Eskimo, who

regard their flesh as a great delicacy. Their fur and hide are made into clothes and ropes, while their intestines form excellent window-panes.

During Julius Payer's Arctic voyage of 1872–74, large numbers of bears were killed for food, and it was discovered that their meat was effective in keeping at bay the dreaded scurvy. The bear's liver, however, is said to be highly poisonous to man, though dogs may eat it with impunity. The male Polar bear roams at large throughout the bitter winter, specimens being found in every part of the vast ice-cap; but the female hibernates during this season, scraping a comfortable lair deep beneath the snow, in which in due time her cubs will be born.

Comical, yet Dignified Penguins

The most characteristic of all the fauna of the Far South are the comical, flightless penguins, which are peculiar to the southern half of the globe, and never wander north of the equator, though they appear as close to it as the Galapagos Islands. There are many species of penguins, all more or less closely alike in their structure and habits, but differing widely in size and marking. Being aquatic birds, they all have webbed feet, and when standing still in their characteristic upright, "human" pose, plant themselves well back on their heels. Their plumage consists of a smooth covering of short, close-growing feathers of peculiar structure, and the head is small and elongated, with a large bill. The penguin's most peculiar feature, however, is its aborted wings, which with countless generations of disuse have lost their quills and the power of flight, though they have been modified into excellent balancing organs and swimming paddles.

Photo: the late H. G. Ponting

A group of penguins—dignified as ever—at Cape Royds, in the Antarctic

Penguins congregate in large colonies, some of which, it is reckoned, may contain the best part of a million birds. Individually they are garrulous birds, and the chatter arising from a numerous colony is beyond all conception. Though the female lays but one egg at a time, and though seals and sea-elephants wreak enormous havoc among them, yet they seem undiminished in number. Sir Francis Drake's companions killed more than 3,000 penguins in one day in the Straits of Magellan, so plentiful were they and so unafraid of man

Penguins seem more at home in the water than on land, and they are incomparable divers, catching fish with an unfailing precision of aim. They are the most amusing and most "human" of all birds—urbane and courteous in their demeanour, meeting strangers with profuse bows and friendly nods; yet, withal, invested with a dignity that nothing can disturb. Concerning their intelligence, opinion has been divided, but it is certain that they evince a high degree of curiosity. Sir Douglas Mawson watched them labouring to build their nests in an overpowering gale in Adelie Land. After a while, instead of persisting unintelligently, they gave up the attempt as hopeless and crouched behind the rocks to await fairer weather. They have been observed to make tours inland in company, for the sole object, apparently, of satisfying their curiosity. The manner of their return to the sea when in a hurry is highly amusing; they skim down the snow-covered slopes and ridges head-first, in the manner of a toboggan, getting up a great speed by working with their feet and flippers.

The most handsome of all these birds is the emperor penguin of the Antarctic mainland, which may stand as much as four feet in height, with a weight of nearly a hundred pounds. The single egg of the emperor penguin is laid upon the ice, which may have a temperature of 60 degrees to 70 degrees Fahrenheit below zero. To prevent it from being frozen, the parent birds in turn support the egg on the web of their feet and cover it with the loose, pendulous skin of their large abdomen. When the young chick at last hatches out, the same method is employed of protecting it from contact with the ice.

The Adelie Land Penguin

The Adelie Land penguin, the only other species found on the main Antarctic continent, is smaller and less dignified than the emperor penguin. The unconventional family life of this species has been graphically described by Mr. J. Gordon Hayes in "Antarctica."

"The scouts appear on the Ross Sea coasts [from the floating pack-ice] in October, being followed in about ten days by the main body. They scratch a small hole in the gravel, if possible, and select stones for their nests, in which they lay two eggs, the second soon after the first. The month's hatching then begins. The parents take it in turns to go into the sea for shrimps, until the chickens get too big for one parent to cope with their prodigious appetites. Both parents then go fishing, while other adult birds each guard twenty or thirty chickens from the skuas. The strongest chickens get most of the food by chasing the parents on their return, until they disgorge. . . ."

The breeding season is over in February, and then the parent birds swim northwards in great numbers to their winter quarters among the floating pack-ice. The young birds, who meanwhile have changed their thick, fluffy down for their adult dress—discarding it in shreds somewhat like the moulting of a serpent—are left to fend for themselves, until they feel strong enough to take to the open sea, when they set off in pursuit of their parents.

Can the Polar Lands be Colonized?

It is very doubtful whether the lands fringing the Polar seas can ever be colonized by man to a sufficient extent to be profitable, for apart from the extreme cold - the temperature rarely rises higher than 50 degrees Fahrenheit below zero, and often falls much lower—by far the greater part of the soil is ice-bound and barren. But it seems quite feasible that the Antarctic, at least, where the climate is drier and more endurable than that of the Far North, should in time become one of the greatest playgrounds of the world, to which people will flock in search of health and pleasure amid the most magnificent scenery in existence. Infectious diseases are unknown in the Far South, for the air is practically aseptic, and it has been described as more exhilarating than champagne. It is so clear that from a single point one can look over 300 miles of country; and so still that the normal tones of the human voice can be heard more than a mile away. In summer time, the crystal-clear atmosphere, the absence of wind and the reflection of the sunlight from the white landscape often make it hot enough to be uncomfortable, even though the ground temperature be many degrees below freezing-point. Above all, perhaps, it is in the pageantry of its stage-lighting that the Far South is supreme. The deep translucent blue of the sea; the rainbow tints of refracted sunlight shimmering on the ice and snow; clouds iridescent with all the colours of the spectrum; golden sunsets that endure for days on end; mock suns, mirages, and the vast, ever-changing panorama of the Southern Lights—all these are things to marvel at and to hoard in the memory for ever.

CHAPTER IV
FLOATING MARVELS OF LUXURY AND SPEED

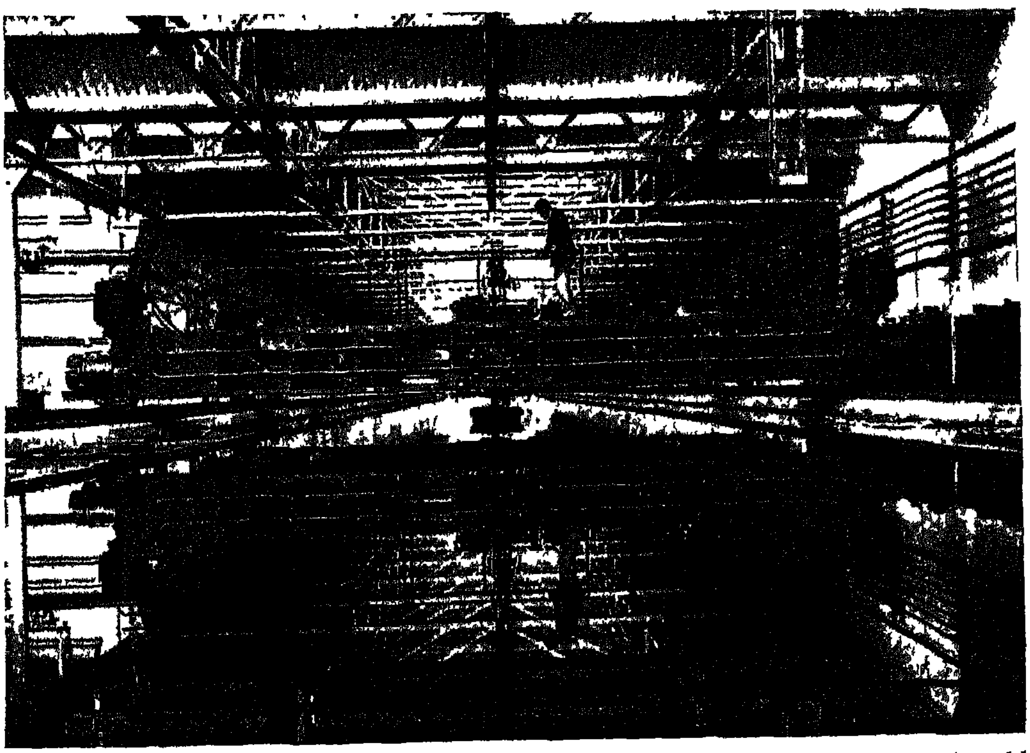
IN 1812 James Bell, the Scottish engineer, built one of the earliest steamships, the *Comet*, which was the pride and wonder of the Clyde. To-day, from the Clydeside comes the largest and most powerful ship in the world, the *Queen Mary*. So tremendous have been the strides in ship construction in a little over a century that could the *Comet* be placed to-day on the *Queen Mary's* upper deck, its total length would be found to be only one-third of the deck-width of the world's greatest liner!

Mechanical Developments

It was in 1785 that James Rumsey, one of the very first experimenters with steamships, drove a small boat under its own steam power on the Potomac River in America, at a speed of four miles per hour. The next century was one of tremendous mechanical developments, and it was soon realized that the steamboat had far greater possibilities than just continuing its original use of towing sailing vessels or barges along canals and rivers Various methods of steamship propulsion were tried but the most popular for many years was the side paddle-wheel.

Early Transatlantic Services

Six years after the appearance of the *Comet*, the *Savannah*, a sailing vessel fitted with paddle-wheels and steam-engine, crossed from her name-port in South Georgia to Liverpool in twenty-seven days The engine and paddle-wheels were in operation for eighty hours only during the voyage But in 1826 a Dutch vessel, the *Curacao*, of 438 tons, which was entirely dependent upon engines and paddles for propulsion, made the first genuine steamship trip across the Atlantic. She was built at Dover, and her first passage to the West Indies on the Dutch mail service took a month The *Royal William*, a steamship built in Quebec, made an eastward crossing in 1835, and



The testing tank at the National Physical Laboratory, Teddington, where the effects of stress and strain on ship models is recorded and much other data collected which is invaluable to the designers and builders of great sea-going vessels

ship owners began to dream of regular steamship services across the Atlantic.

The first steamship built specifically for transatlantic travel was the *Great Western*, a vessel of 1,320 tons that was constructed to the design of I. K. Brunel. In 1838 this ship made the journey from Bristol to New York in fifteen days, arriving at that port a few hours after her rival the *Sirius*, which had sailed from Cork in Ireland three days previous to the *Great Western's* departure from England.

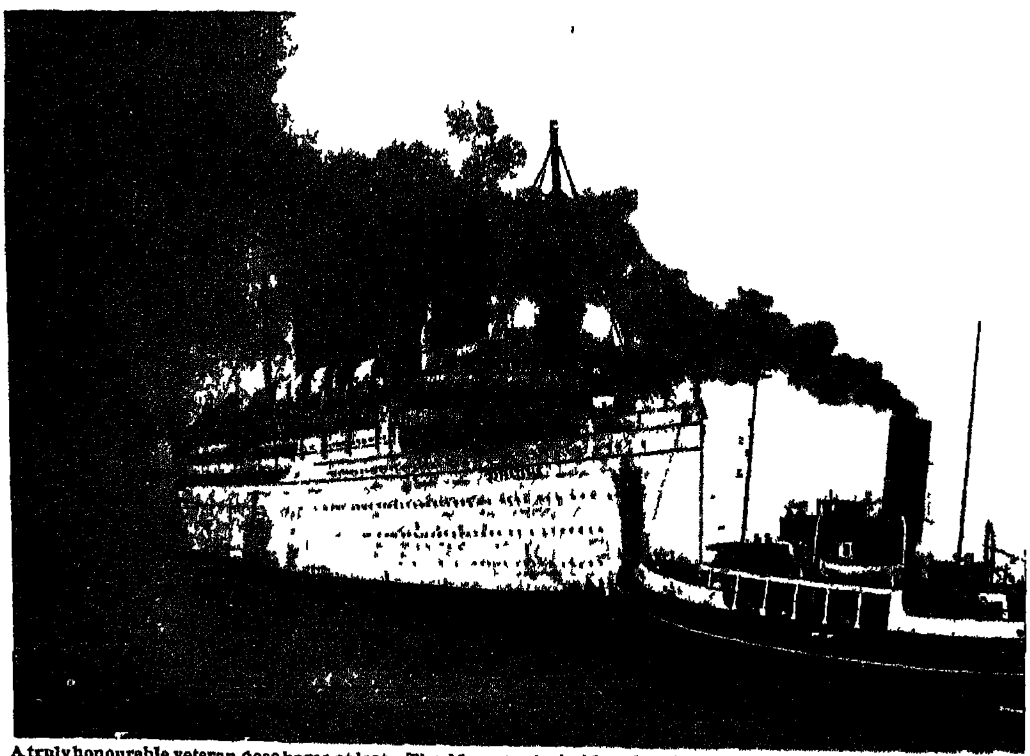
Birth of the Cunard Line

It was not until Samuel Cunard in 1840 took the bold step of building four sister ships that a regular transatlantic service could be offered to the public. A company was formed with a capital of £270,000 and the contract for carrying mails was secured. Cunard's four ships were built of wood; each was 207 feet long, and carried 115 cabin passengers and 225 tons of cargo at an average speed of 8½ knots. The first-built of the quartet was the *Britannia*, 1,150 tons; but for speed she was eclipsed by the *Acadia*, which made a westward trip at 9·25 knots and the return voyage at 10·75 knots. These ships were not the fastest in their day, but the regularity of the service compensated for their somewhat slower journeys.

For some years the wooden Cunarders had a large share of the transatlantic trade, but in 1847 American shipyards began to build speedier and more comfortable paddle-ships. The American vessel *Adriatic*, built in 1851, of 5,888 tons gross with engines of 4,000 i.h.p., was capable of a speed of 13½ knots. With the introduction of a screw-ship for transatlantic work by the U.S. Inman Line, competition between that company and the Cunard Line in the 'sixties became very keen. The Inman Line *City of Brussels* held the record with a speed of 14·66 knots eastward in 1867.

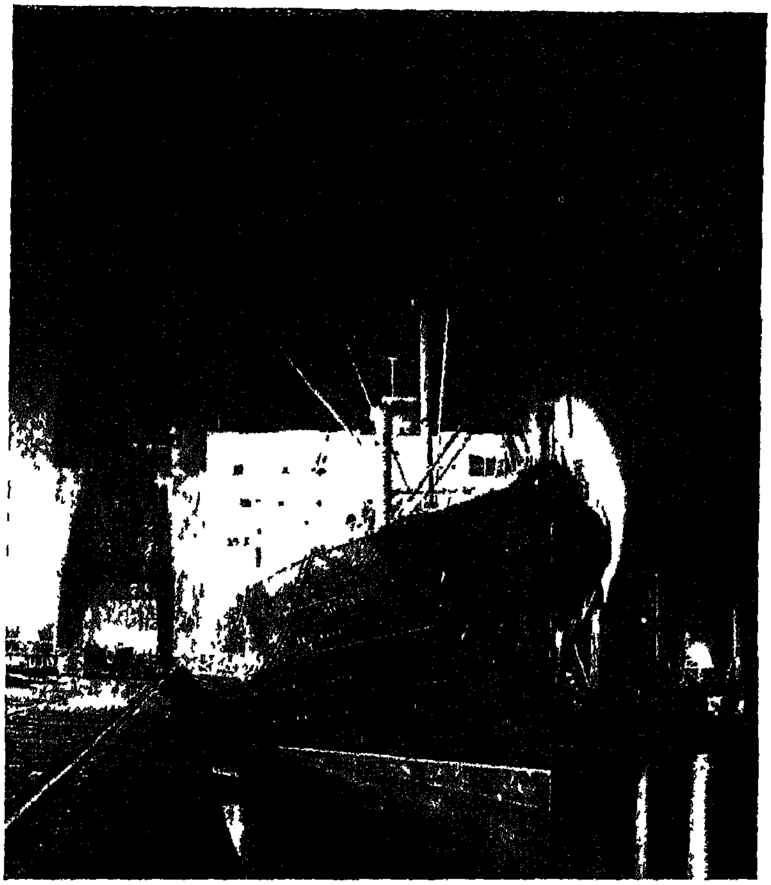
The White Star Line

A year or two later another rival company appeared on the scene. This was the White Star Line, whose ships were built by Harland and Wolff of Belfast, in Ireland. Luxury and comfort for passengers was the main object of this new service, speed being a secondary consideration, although the vessels were soon outbidding the Cunarders in



A truly honourable veteran goes home at last. The *Mauretania*, holder of the Blue Riband of the Atlantic for 20 years, leaving Southampton on July 1, 1935, for Rosyth, there to be broken up. Since 1907 she had steamed 2,500,000 miles between England and America

speed rivalry with the Inman Line. The White Star *Britannic* broke the record for the eastward trip in 1876 with a speed of 16 knots. The following year both *Britannic* and *Germanic*, with a speed of 15·5 knots, secured the record for the run westward.



The great transatlantic liners are often called on to make a rapid "turn round." Here is the *Aquitania* at Southampton completing a full replenishment of stores and fuel in 27½ hours

By 1889 the contest lay between four new ships—the White Star's *Teutonic* and *Majestic*, and the Inman *City of Paris* and *City of New York*. All were propelled by twin screws, and the comfort of passengers was a major consideration. In 1893 the *City of Paris* made a westward trip with an average speed of 21 knots. The best that the Cunarders could do was a little over 20 knots. Four years later the North-German Lloyd company launched the first of a fleet of luxury ships. Their *Kaiser Wilhelm der Grosse* was 649 feet in length, and it was not long before she took the Blue Riband, making the eastward trip at an average of 22·8 knots and the run westwards at 22·7 knots.

Meanwhile the Inman Line had relinquished the contest, leaving the White Star, Cunard and the North-German Lloyd lines to compete for the Atlantic express traffic.

With the financial assistance of the British Government the Cunard Line built the *Lusitania* and *Mauretania*, which were launched in 1907. The former was built on the Clyde and had an overall length of 787 feet, a beam of 88 feet and a total depth of 60½ feet. Her displacement was 41,590 tons. The greatest interest in both ships, however, was centred in the enormous turbine engines, of 75,000 h.p., that turned the four screws. The *Mauretania* was built on the Tyne, but differed only in minor points from her sister ship. For seven years the German-built liner *Deutschland*, launched in 1900, had been undisputed mistress of the Atlantic when the *Lusitania* made her maiden voyage. Then, with a speed of 23·61 knots per hour the English liner broke the *Deutschland's* record of 23 knots. Two years later the *Lusitania* brought her average westward speed up to 25·01 knots. But the *Mauretania*, once she got into her stride, proved faster than her sister ship, making in 1909 the eastward journey at an average of 25·89 knots and the return run at 26·06 knots. The journey from Cork to New York was covered in four days, ten hours and forty-one minutes, a record unrivalled for twenty years. As time went on, the *Mauretania's* performance improved, and when twenty years old she steamed to the rescue of a cargo ship at a speed of 29 knots. In 1929 she made a westward crossing at an average speed of 27 knots. When first put

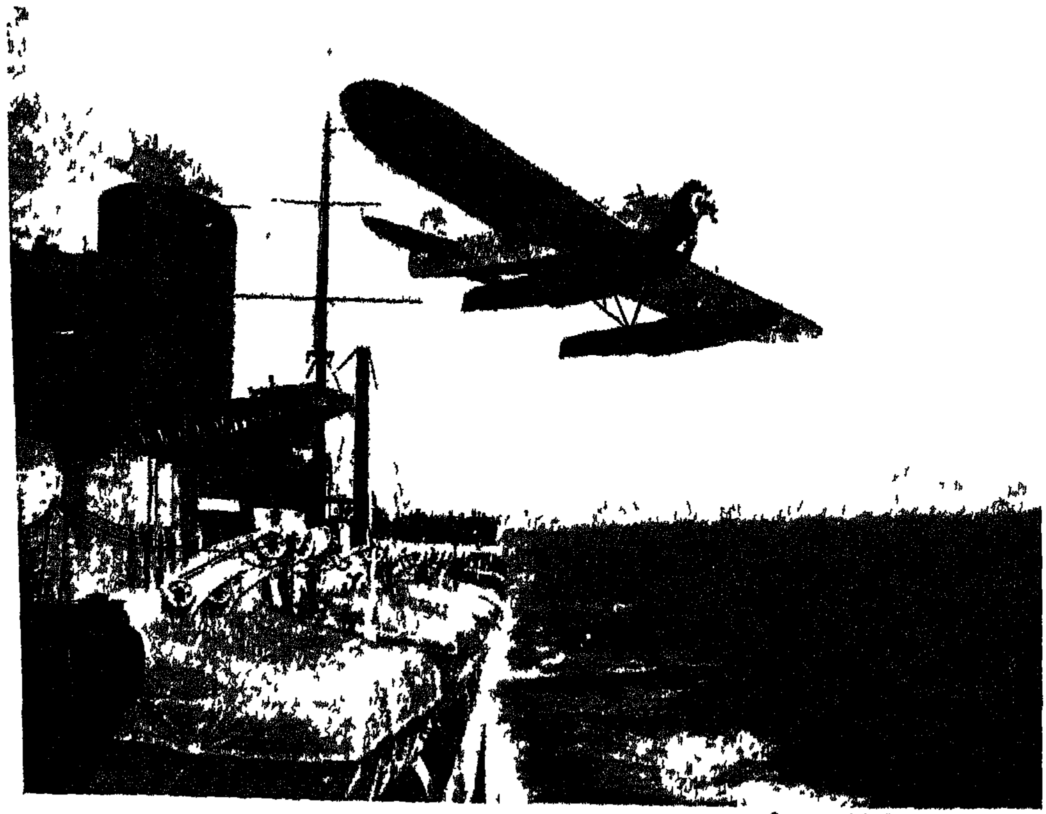
into service these vessels consumed 1,000 tons of coal per day. In 1919 the *Mauretania* was converted to oil burning. *Lusitania* was torpedoed and sunk in 1915.

Just two years before the Great War the Hamburg-American Line, owners of the *Deutschland*, answered the challenge of the Cunarders by laying down even bigger ships. Great speed was not aimed at, but luxurious appointments and hotel comforts were provided in order to attract cabin passengers. The first of these vessels was the *Imperator* (since the War the Cunard *Berengaria*), with a length of 906·7 feet overall and a beam of 98·3 feet, her gross tonnage being 52,226. The second ship was the *Vaterland* (later the *Leviathan*, belonging to the U S. lines), which was 950 feet long over all and had a gross tonnage of 48,943. The third liner, the *Bismarck*, now known as the *Majestic*, is six feet longer than the *Vaterland*, and has a gross tonnage of 56,621.

The Great War interrupted the building of luxury liners as well as causing the loss of several of them—notably the *Lusitania*. After the War new ships were constructed, the Cunard line producing five comfortable 20,000-ton vessels and the Hamburg-American company building four each of 21,000 tons, and capable of a speed of 16 knots.

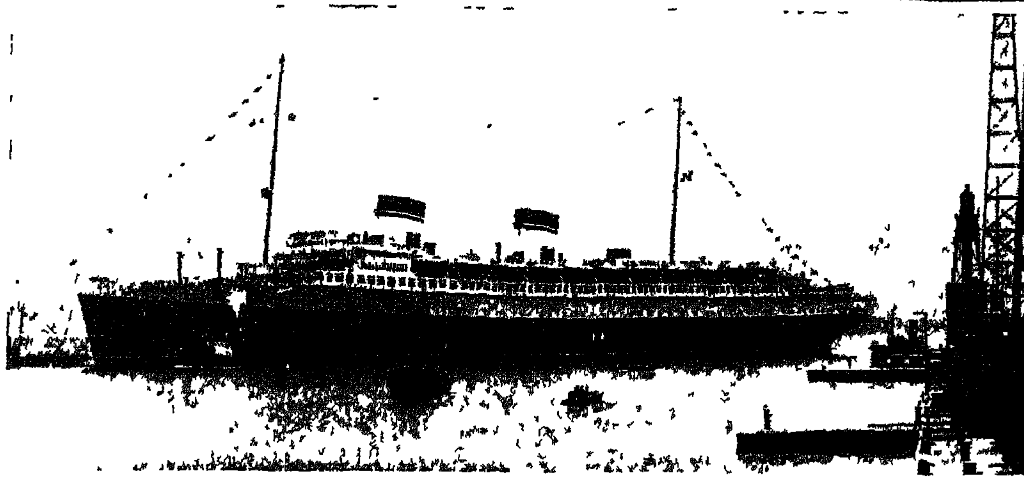
Blue Riband of the North Atlantic

By 1926 the liner casualties of the Great War had been made good and shipping competition began to be keener once again. In that year a French line, the Compagnie Générale Transatlantique, built the *Ile de France*, a ship of 43,153 tons gross, with direct-acting turbines of 52,000 h.p. There were six pre-war vessels—the *Majestic*, *Leviathan*, *Berengaria*, *Mauretania*, *Aquitania* (Cunard) and *Olympic* (White Star)—all of larger dimensions on the transatlantic route, but the new liner was fitted with more up-to-date furnishings and appointments. Well-known artists and sculptors helped to decorate and embellish her main apartments and her beautiful chapel; while the provision of five electric passenger lifts, four goods



Courtesy of the North-German Lloyd

In order to expedite delivery of transatlantic mails the *Bremen* carries a fast seaplane which is catapulted into the air when the liner arrives within a few hundred miles of land



Courtesy of Italian Lines

Italy's bid for North Atlantic supremacy was successful, and in 1933 the *Rex* captured the record from the German liner *Bremen*. The great vessel is a wonderful sight at night, while the *Conte di Savoia* (top), another famous Italian boat, has equally impressive lines

lifts, and a controlled heating and ventilating system all served to attract passengers.

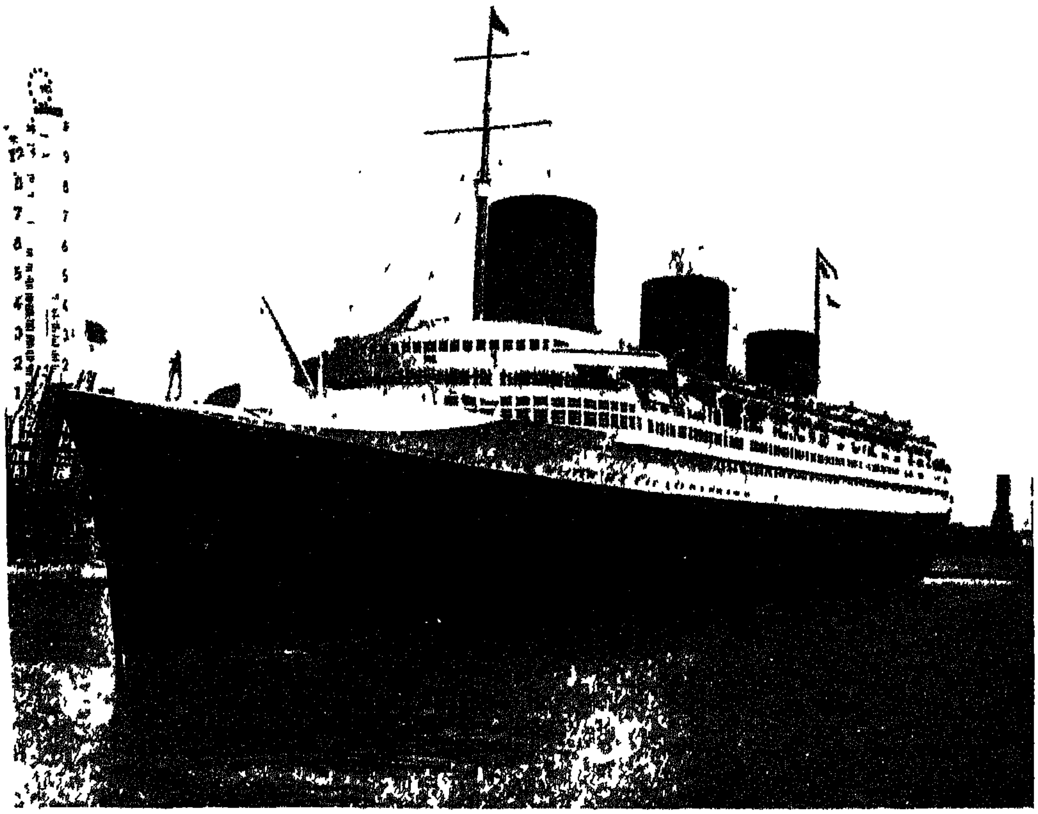
The North-German Lloyd company thereupon took up the challenge and laid down two ships, the *Europa* of 49,746 tons gross and the *Bremen* of 51,656 tons. Both have geared turbines taking steam at a boiler pressure of 375 lb. to the square inch, the output being 120,000 h.p. The design of the two vessels embodied many new features, one being the bulb bow under the waterline. The *Bremen*, launched in July, 1929, averaged 27·83 knots on her maiden voyage, making the return journey at 27·9 knots. The voyage from Cherbourg to New York took four days, seventeen hours, forty-two minutes, but the *Bremen* later lowered her own record eastward by thirty-six minutes. Her sister ship the *Europa* was seriously damaged during construction, but in February, 1930, was ready to take her place on the trans-atlantic service. She made a record westward trip, averaging 27·91 knots.

The monopoly of American tourist traffic by northern European lines stirred the Italian government to action; certain rival Italian shipping firms pooled their forces to form the "Italia" Line, which would bring passengers to Mediterranean ports. As a result the *Rex* and *Conte di Savoia* were built. The *Conte*

di Savoia is in every way the smaller ship and carries an important innovation for a large passenger liner—the stabilizer. This consists of three gyroscopes, each with a flywheel thirteen feet in diameter and weighing 175 tons. With this plant the vessel cannot roll more than two and a half degrees to either side even in the roughest weather.

The *Rex* took the speed record from the *Bremen* in August, 1933, when she attained a speed of 28·92 knots on a westward journey. A spacious and luxurious vessel, the *Rex* is mately 20,000 electric lamps on board. A system is installed for artificial ventilation of the rooms with hot or cold air.

The hull is divided into fifteen compartments, each fitted with watertight doors workable from the bridge. The driving machinery is divided into groups, located in various watertight compartments in such a way that even if the vessel is seriously damaged and one-half of the turbines and boilers are put out of commission the rest of the plant can still function to propel the



Courtesy of the French Line—C G T.

The French liner *Normandie*—holder of the North Atlantic speed record in 1935—leaving the harbour at Le Havre

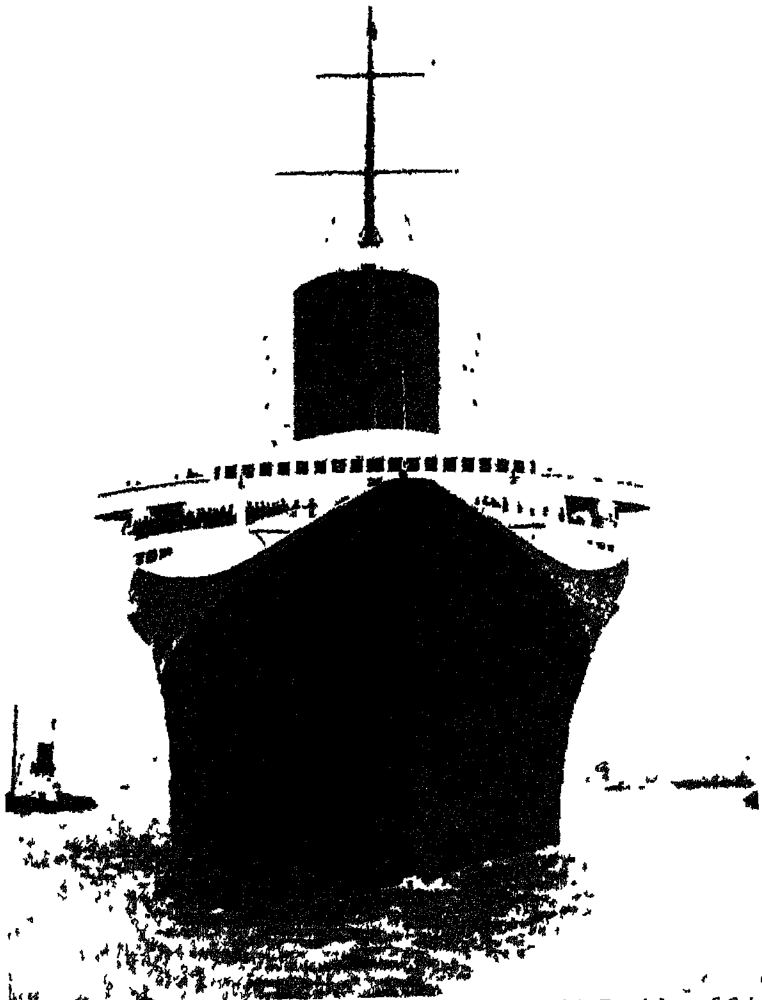
880 feet long with a beam of 102 feet. Her gross tonnage is 51,062, and the height to the bridge is 120 feet. The *Rex* has four independent groups of turbines, each driving a separate screw. Liquid fuel—naphtha—is burned to heat her fourteen boilers, and her two oval, streamlined funnels rise fifty-one feet above the sports deck. To generate the current needed for electric lighting and other services there are three turbo- and four Diesel-generators. The output of the turbo-generators is sufficient to illuminate a town of 150,000 inhabitants. There are approxi- vessel. The *Rex* carries twenty-four life-boats, twenty-two of them motor-driven; and automatic fire alarms communicate direct with the bridge.

This floating palace has eleven lifts; recreational amenities include a squash rackets court, gymnasiums, and swimming pools. There are children's playrooms and a marionette theatre, while the grown-ups have a fine concert-hall and theatre of their own. There is a church, of course, and the other public apartments include magnificent dining-, drawing- and smoking-rooms, and lounges.

The competition for the Blue Riband of the Atlantic, as readers will doubtless have noted, had by now become a matter that touched the national prestige. Thus challenged by the Italian builders, the French in turn were put upon their mettle, and State assistance was given for the building of a yet greater and speedier liner that should offer still more luxury and comfort. The Compagnie Générale Transatlantique laid down in 1930 the *Normandie*, built in the Penhoët shipyard at St. Nazaire, the port at the mouth of the Loire. This great vessel took four years to build, at an approximate cost of £8,000,000. A new berth had to be constructed, part of it projecting into the sea, as the space ordinarily available was not large enough. On May 29, 1935, the four-screw liner with an overall length of 1,029 feet 5 inches, beam of 119 feet 5 inches and a gross tonnage of 82,799 left St. Nazaire on her maiden voyage to New York. The *Normandie's* average speed of 29·94 knots for the journey proved her to be the fastest liner then afloat. The tonnage figures are those given by the owners in 1936.

During her best day's run she averaged 31·37 knots, equivalent to a land speed of 36 m.p.h. The average speed for the whole return trip was 30·34 knots.

The *Normandie's* powerful engines, capable of producing such speeds, are of the turbo-electric type. The initial energy to drive the massive machinery comes from twenty-nine main water-tube and four auxiliary Scotch boilers. Steam at a pressure of 400 lb. per square inch is delivered at a temperature of 350 degrees centigrade. The boilers are installed in spacious rooms, where the stokers need only overlook the oil-fuel burners to see that they are functioning properly. The floors of the boiler and engine rooms in the *Normandie* are almost as clean as were the holy-stoned decks of the sailing ships of other days.



Courtesy of the French Line—C G T

An impressive bows-on view of the *Normandie* outward bound from Le Havre. Note the enormous size of her funnels in proportion to her beam

The steam from the boilers drives four main turbo-generators, each with an output of 33,400 kilowatts, which generate an alternating current at 5,000 volts to drive the four main propulsion motors. These motors are of the three-phase, synchronized

type and their total maximum output is 160,000 h.p.; they turn the propellers at 240 revolutions a minute.

In addition, electricity is provided for lifts, refrigeration, lighting, cooking, etc.; and for this an auxiliary plant is installed. The total electric load which the ship can provide would be more than sufficient to drive the whole of London's underground railways during the heaviest business rush. In the kitchen everything is run by electricity, including the chief range of ovens, fifty-five feet long. A huge cold-storage section has eleven great rooms for holding foodstuffs, each set at a different temperature; while a special refrigerator makes possible the daily renewal of fresh flowers in the florist's shop. Many miles of pipes bring fresh air into every part of the vessel, and an equal mileage of piping is used to force out the stale air. The *Normandie* has a system of drainage equal to that of a highly developed township. The water poured out in the 321 baths, 555 showers and 1,901 wash basins is collected in a huge conduit and finally ejected by compressed air into the sea through twelve holes below the water-line.

The hull, built mainly of high-tensile steel, is of a novel design calculated to reduce water resistance. High-flared bows, capped with a reinforced turtle-back deck and buttressed breakwater, are designed to throw off any heavy seas, so that high speeds can be maintained even in the roughest weather. There are twelve decks on the *Normandie*, although only five of them extend the whole length of the ship. Like all modern ships of the French line, the sun-decks are clear of ventilators, air fans, and other details, these being hidden below the "turtle-back" or in the superstructure. The after-ends of the various decks are arranged in a series of stepped terraces, providing open-air promenades for passengers of every class. The main deck terrace has an open-air swimming pool for tourist class passengers. The larger first class pool is on "C" deck amidships.

A Wonderful Dining-room

It is impossible to describe in a short space the beauties and marvels of interior decoration which make the *Normandie* a veritable floating palace. The grand dining-room has been contrived without a single supporting pillar in its 300 feet of length and 31 feet of height. Seven hundred persons may be accommodated at the 250 tables. The walls are of moulded, engraved and chiselled glass, whilst the lighting comes from thirty-eight luminous glass fitments on the walls and twelve tall glass standards rising from the floor. Four great gilded bas-reliefs alternate on a background of red marble with inlays of glass. A monumental statue of "Peace," by the French sculptor Dejean, towers above the diners. Eight small side rooms for private parties and a circular banqueting room, all decorated by well-known painters, lead from the main dining saloon.

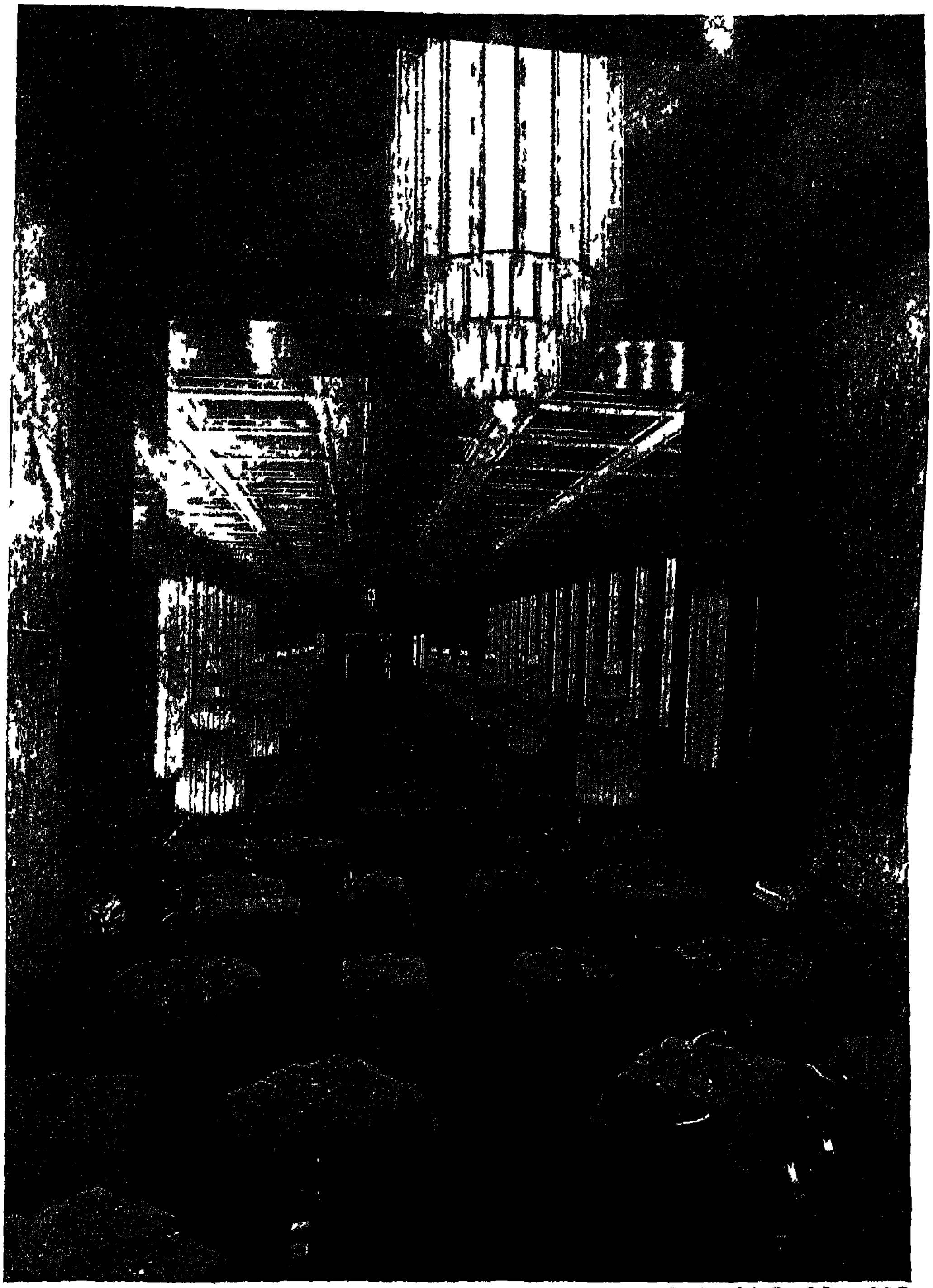
There is, on the sun-deck, a children's playroom with a Punch and Judy show, "elephant" chairs and rocking-horses; this apartment has a star-spangled ceiling. In the adjoining children's dining-room, the walls of which are gaily decorated with troops of elephants, special menus are arranged for the little passengers. The *Normandie's* beautiful chapel, in the Byzantine style, has doors in cloisonné enamel. The handsome theatre, decorated in silver, accommodates 380 persons, its stage being larger than many in Paris or London.

The *Normandie* has accommodation for 1,972 passengers and carries a crew of 1,345. There are fourteen special suites with private dining- and sitting-rooms. In first class cabins all the beautiful wood panellings are asbestos lined, and the furniture is fireproof. Automatic fire-alarms are fitted throughout the ship and the latest fire-fighting appliances are available for use by a special fire brigade.

Britain's Atlantic Challenge

About the same time that plans were being made in France for the building of the *Normandie*, the Cunard Line in England was discussing the production of a great new vessel. Temporarily known as "534," this ship was laid down at John Brown and Company's yard on Clydebank, in December 1930. Work was suspended a year later owing to the financial depression. The government came to the company's assistance and construction was resumed in April 1934; in the interim the White Star Line had merged with the Cunard. In the autumn of 1934 the ship was launched by England's gracious Queen and named *Queen Mary* after her. The great Cunard-White Star liner left the Clyde in March 1936, and made her maiden voyage in the following May.

The gallant *Mauretania*, which held the Blue Riband of the Atlantic for twenty years, was sold to shipbreakers in 1935 to make way for the new giant. Already the U.S. *Leviathan* had gone, and a few months later the White Star *Olympic* shared the same fate. As the running costs of the



Courtesy of the French Line—C G T.

The magnificent first class dining-room of the *Normandie*. Measuring 43 feet by 300 feet, it is the largest public room on the ship. Two prominent architects—MM. Patout and Pacon—were responsible for the striking interior decoration

Mauretania had always been very great, the company decided to alter their policy and to attempt the regular transatlantic service with only two giant sister ships. The *Queen Mary* is the first of them. But though the famous old *Mauretania* was broken up, much of her lovely panelling took on a new lease of life in the rooms of her successor.

Built for Safety

The hull of the new vessel has an over all length of 1,018 feet and a beam of 118 feet. From keel to funnel top she is 180 feet high. Special high-elastic-limit steel has been used for the hull, whose construction has involved the use of over 10,000,000 rivets. As in all large modern ships, the new vessel has two bottoms, an outer and an inner, running the full length of the machinery spaces. Altogether 160 watertight compartments are enclosed between the two "shells," and the whole ship can be shut off by mechanism on the bridge into eighteen watertight sections. The rudder alone weighs 140 tons and is the largest built for any ship. The diameter of each oval funnel is thirty feet, wide enough to house three "Royal Scot" engines placed abreast.

The *Queen Mary* is driven by four sets of Parsons' single-reduction geared turbines supplied with steam from twenty-four high-pressure water-tube boilers, which are fired by oil. Each of the four manganese bronze propellers is driven by a separate set of machinery, comprising a large gear wheel, fourteen feet in diameter, turned by four of the turbines. This form of propulsion, it is claimed, makes for low running costs, together with stability, absence of noise and freedom from vibration.

Apart from the propulsion engines, the ship has an enormous electric plant, comprising three 1,300 kw. turbo-generators drawing steam from three additional boilers. About 30,000 lamps are installed and the 4,000 miles of cable to run the energy through the ship would be sufficient to stretch the whole length of the Amazon River. The deck machinery throughout the ship is electrically operated, and the life-boats can be quickly lowered by electrical operating gear.

The greatest electric load supplied by the hotel service generators is that required for the catering galleys, where ranges, ovens, fryers, mixing machines, toasters, waffle-irons, dish-washing machines and ice-cream machines are all electric. For use in case of a breakdown, small emergency generators driven by petrol-paraffin engines have been installed.

In the decoration of the public rooms, which cater for every form of social entertainment and relaxation, many famous artists were engaged. The main restaurant has an imposing work at one end by Philip Connard, R.A., and at the other McDonald Gill has created an immense decorative map twenty-four feet by fifteen feet, which depicts the North Atlantic Ocean. Sailing across this is a constantly moving illuminated miniature of the *Queen Mary*, her position automatically indicating that of the great ship itself. Tom Webster has amusing caricatures adorning the walls of the gymnasium, whilst the aluminium ornaments over the transport and airways office are the work of Maurice Lambert.

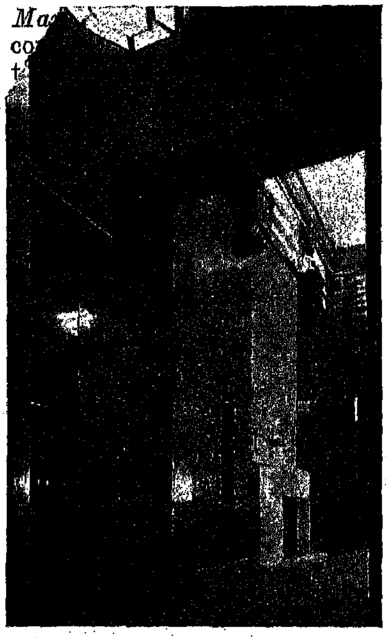
First class suites comprise sitting-room, bedroom, servant's room, boxroom and private bathroom. Even third class staterooms are equipped with fitted wardrobe, dressing-table, comfortable chairs and carpets; and hot and cold water are laid on. Each small room, too, has its own electric fan and directional ventilation, whilst the ceilings are encased in wood that hides the steelwork of the ship. There is an indoor swimming pool for tourist passengers, in addition to those for other voyagers; and altogether nearly two acres of deck space is available for promenading and sports.

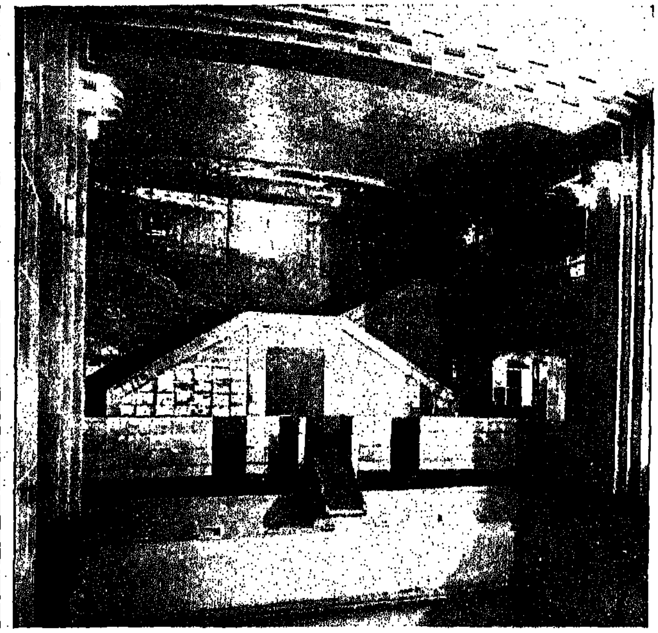
Docks for Thousand-feet Liners

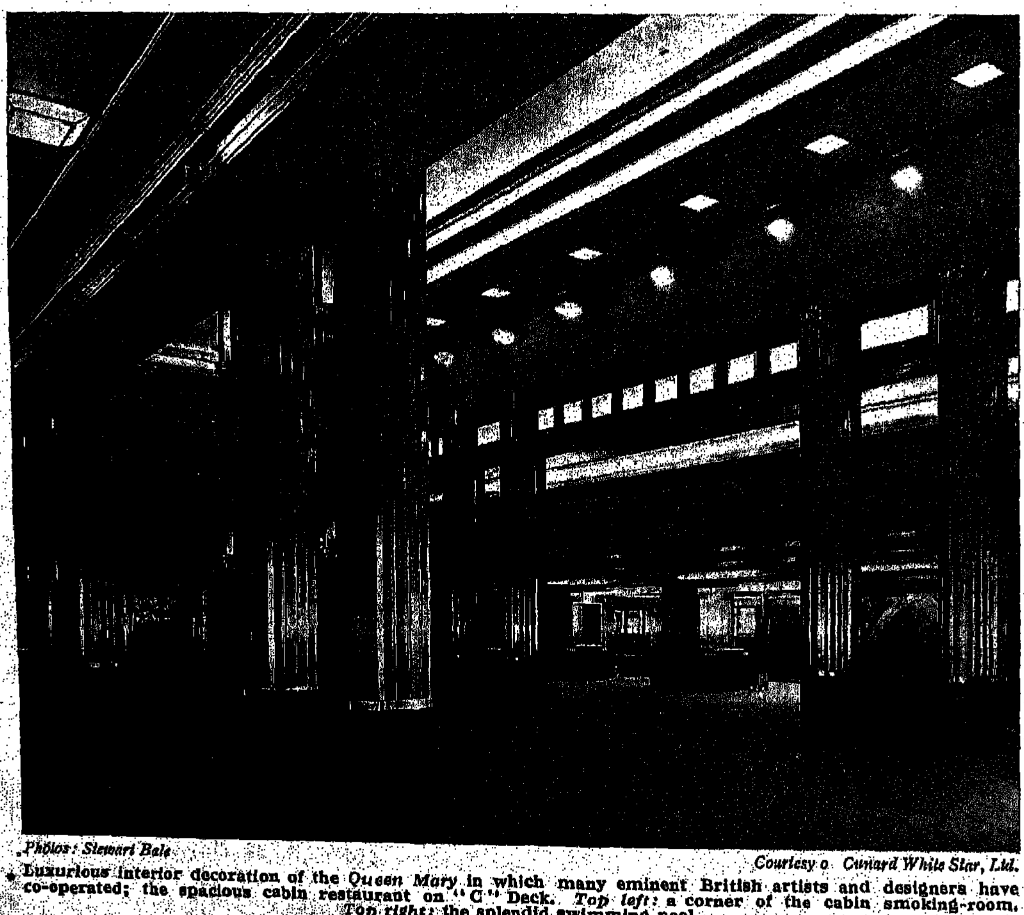
As the ocean greyhound grew longer and wider and deeper, its accommodation in docks and ports and harbours came to be something of a problem. By the time the steamship had come into its own the best sites for ports, harbours and docks had already been developed in all the principal countries of the world. But there were some with better facilities for growth and expansion, able to provide deep water and adequate protection from rough seas, which lay at easily accessible points on the maritime highways, and which possessed dry docks and floating docks for repair work. Here progress and enlargement went forward steadily, so that the great new ships could enter, and leave conveniently, and receive that proper attention they needed.

The natural protection which the port of Southampton receives from the Isle of Wight made it, from very early times, a valuable harbour. Even in 1434 an elementary type of dry dock was built there. It was little more than a narrow embayment in which a ship was floated at high tide. When the tide fell, a temporary wall of clay, timber and brushwood was built across the mouth

The great Cunard-White Star liner *Queen Mary* entering the King George V Graving Dock at Southampton at the termination of her first journey from the Clyde shipyard where she was built. Note the 50-ton travelling crane in the foreground

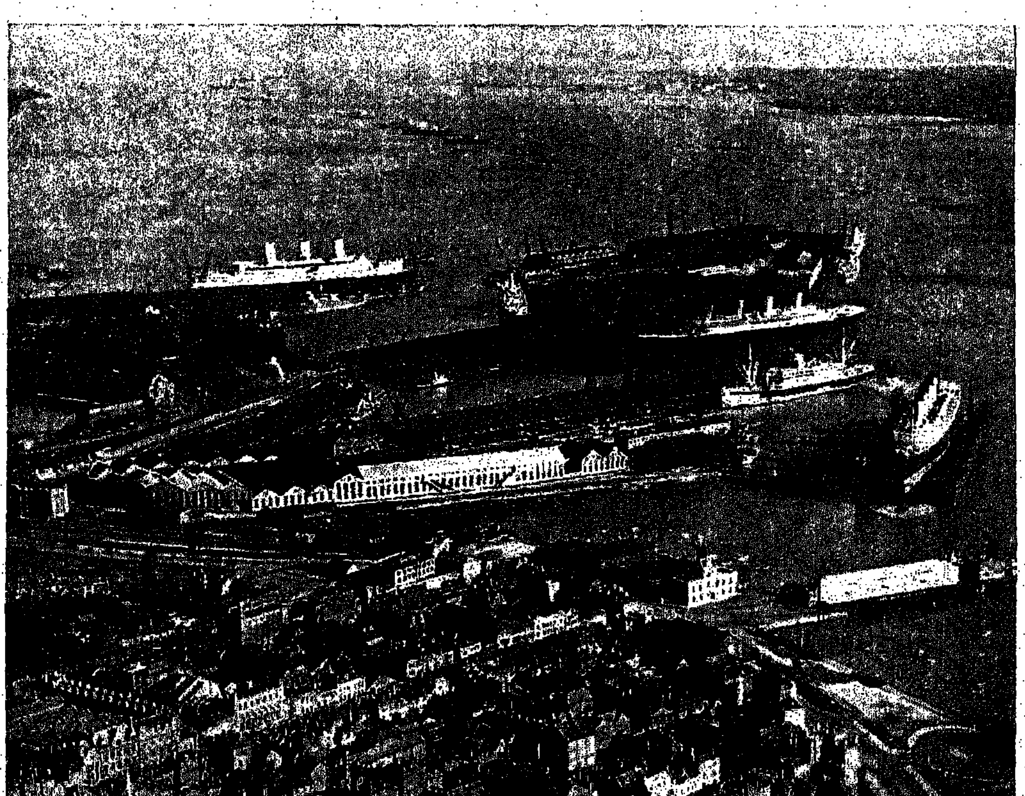






Photos: Stewart Bale *Courtesy o Cunard White Star, Ltd.*

Luxurious interior decoration of the *Queen Mary* in which many eminent British artists and designers have co-operated; the spacious cabin restaurant on "C" Deck. *Top left:* a corner of the cabin smoking-room. *Top right:* the splendid swimming pool



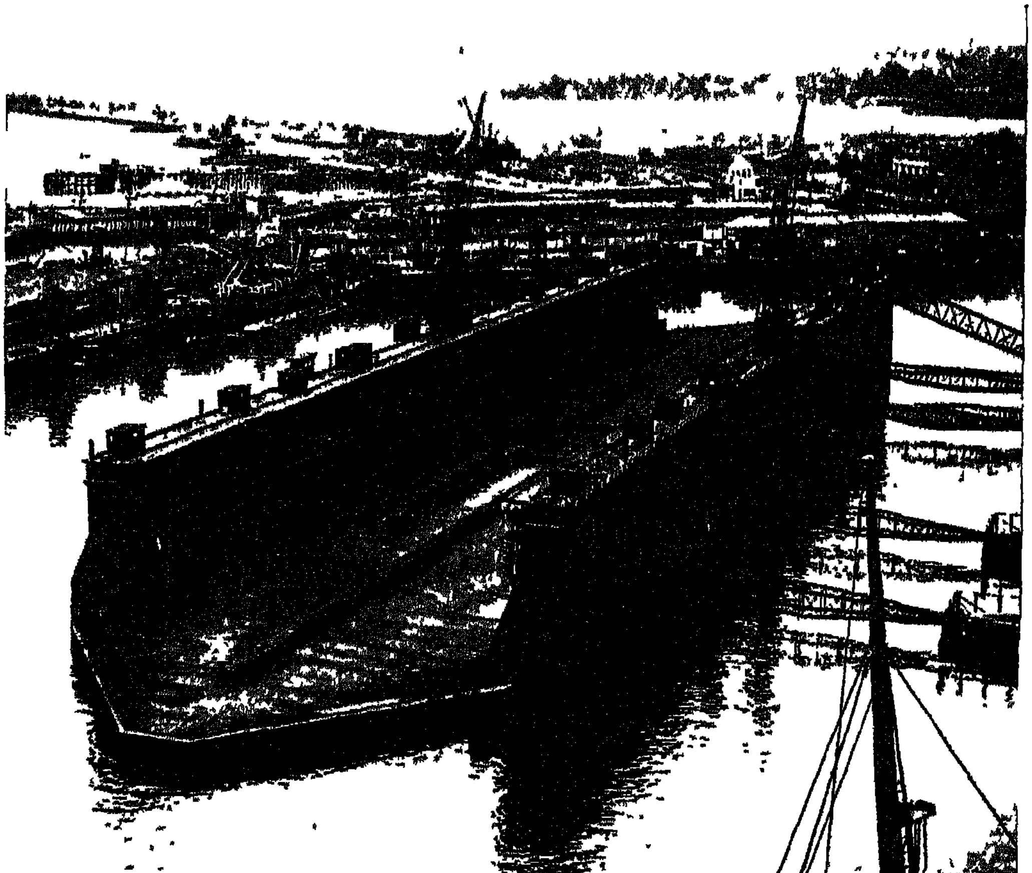
Two of the world's busiest docks *Photo: Aerofilms, Ltd.*

Southampton, where can be seen the *Empress of Britain* (top left), *Olympic* (top right), and *Mauretania* (in floating dock). Tilbury (above) with the *Belgenland* and three Orient liners

and the ship left high and dry for repairs to be effected.

Southampton is not only well sheltered, but has a fairly deep natural harbour with the advantage of double tides, and a position at the head of Southampton Water at the confluence of two small rivers. Therefore, with only a moderate amount of dredging and the construction of quays jutting out into water forty feet deep at low tide, it became an easy matter for the largest liners to berth at any state of the tide. This great natural and economic advantage has made Southampton the premier port in England for the giant transatlantic liners.

Here, excellent facilities for cleaning and repairing vessels, unloading cargoes and entraining passengers are available. The world's largest dry dock, completed in 1933, lies in the harbour. Known as the King George V Graving Dock, it was primarily constructed in readiness for the new Cunard-White Star liner then building. But it was designed with an eye to the future and is capable of accommodating a vessel up to 100,000 tons. For its construction some 2,000,000 tons of earth were first excavated and a concrete floor twenty feet thick was laid. This, together with the strong buttressed walls, took 750,000 tons of concrete. A sliding steel gate or caisson weighing 1,800 tons closes the dock when a ship has entered. The water content—some 58,000,000 gallons—can easily be pumped out in about four hours. The dock is provided with two travelling cranes, one lifting fifty tons and the other ten tons.



The world's largest floating dock at Southampton, which is 860 feet long and can accommodate vessels up to 60,000 tons

At Southampton, too, there is the world's largest floating dock, with an over-all length of 860 feet. This enormous hollow steel trough accommodates a ship of about 60,000 tons and can be submerged to accommodate vessels drawing *thirty-eight feet of water*. The giant liner *Berengaria* has been repaired

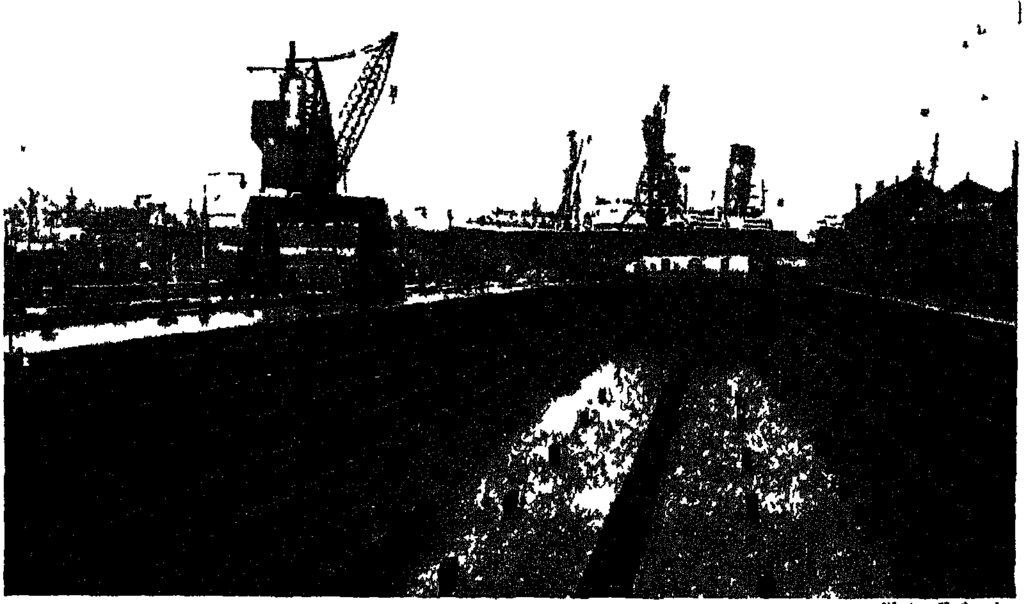
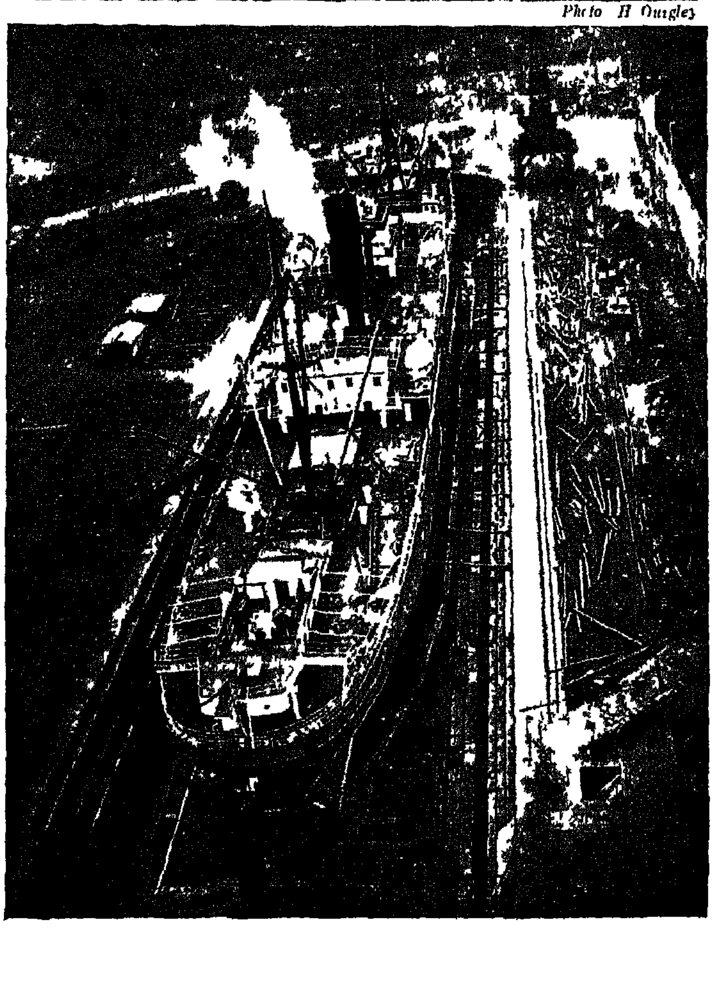


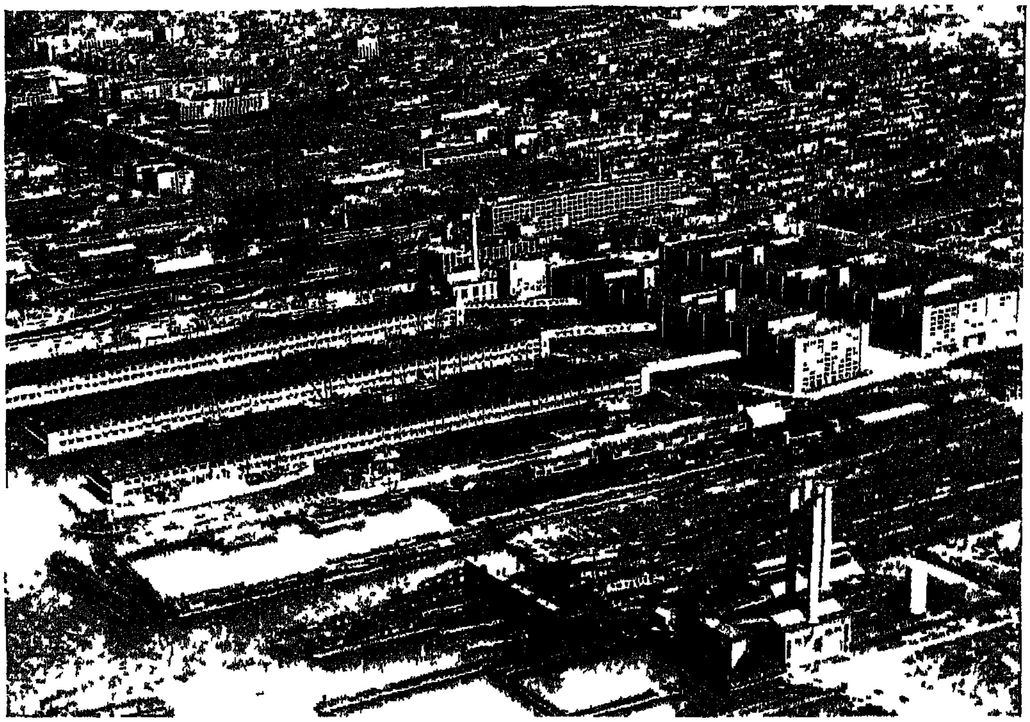
Photo H Quigley



Where ships can be cleaned, repaired or overhauled. Dry docks at Cessnock, Glasgow and (*bottom*), Royal Albert Docks, London. The "match-sticks" on the dock-side are actually the size of telegraph poles

in this dock, after being safely shored up by keel and bilge blocks and electrically manipulated girder shores operated from every side of the dock

Although Liverpool has enjoyed for some centuries a great reputation as a port, its position gives rise to difficulties in accommodating modern giant liners A powerful tidal scour makes a deep natural channel in the middle of the River Mersey, but Liverpool's docks—with the exception of the more recent Gladstone Dock—cannot be entered by large vessels until the water has risen above half-tide level. To obviate this difficulty a floating landing stage nearly half a mile in length was built to allow Atlantic liners to berth *alongside* and



Great freight-handling docks at New York, from the air. The New York Dock Co 's docks at Brooklyn, with the Bush Terminal docks beyond

take on or disembark passengers at all times.

The French port of Havre, originally constructed in sheltered water at the mouth of the River Seine, has since been extended considerably seawards. An outer harbour, enclosed by long breakwaters, provides additional accommodation demanded by the port's increasing trade. In 1927 a dry dock 1,023 feet long, 125 feet wide and 52½ feet deep was opened for the use of the large French liners then either planned or in course of building. One of them, the *Ile de France*, has since been overhauled in this dock and even larger vessels are capable of being accommodated there.

Like Southampton, New York harbour is endowed with great natural advantages. Sheltered by Long Island, Staten Island and Sandy Hook, New York has easily accessible and ample deep water channels, with a maximum tidal range of only five feet, and these advantages render both the outer and inner harbours excellent for docking large vessels. Channel deepening has been carried out consistently, and the berths alongside the new piers have a depth sufficient even for the largest liners.

CHAPTER V

THE OCEAN'S POWER OF DESTRUCTION

THE waters of the ocean are never at rest. Day after day, throughout the many millions of years of the earth's history, the insatiable jaws of the sea have been steadily at work without pause or respite—tearing away fragments of the land in one part of the world, grinding them to powder, and laying them down to form fresh rocks in places, perhaps, very far distant; and this unceasing war of attrition will be carried on inevitably until the life of our planet comes to an end. It is fortunate that the ocean tends to give us back with one hand—in the shape of new land—what it takes with the

other, and perhaps in the long run mankind will never be sorely stricken by its relentless appetite, though individual nations may have their boundaries severely reduced.

The Sea's Powerful Ally

The battering power of the sea—concerning which we shall have more to say later—is dependent chiefly upon its powerful ally the wind, which raises the waters in fury; but the work of transporting the crushed materials, of laying down new land and altering the contour of the ocean bed is chiefly performed by the currents, which in turn are largely set in motion by the tides. Roughly, twice in every 24 hours, as everybody knows, the combined gravitational pull of the sun and moon heaps up the waters in a great flattened wave, which goes sweeping round the world —a natural phenomenon which happens on so great a scale that, though of supreme importance to navigation, it is for the most part familiar and unsensational. Sometimes, however, normal tidal waves attain the dignity of a grand spectacle, especially in funnel-shaped estuaries and bays with a shallowing floor, where the advancing water may be hemmed in and deepened enormously in consequence. The greatest range of tide known is that which sweeps up the Bay of Fundy, the long, narrow inlet of Nova Scotia, where the spring tides of the Atlantic may be piled up to a height of seventy feet above low water, rushing on in a swirling torrent which is a constant danger to shipping.

The Severn Bore

When the spring tide rushes up the river Trent it heaps up the advancing current into an "aegre," or wall-like wave of water, that may reach a height of five feet. More impressive still is the "bore" of the Severn, which is caused by the constriction of the tides of the Atlantic by the Bristol Channel, and which has exacted a heavy toll of shipping and human lives. Frank Buckland, the celebrated naturalist, thus described this tide on the Severn:

"I heard in the far distance a peculiar,

The Severn "Bore"—an extraordinary natural phenomenon caused by the constriction of Atlantic tides by the Bristol Channel

dull, heavy, rushing sound, but could see nothing. . . . In a few minutes I saw a curved white line, stretched right across the channel, coming round the corner of the river. With a fearful velocity this white line advanced steadily up the river, and as it neared us I saw that it consisted of a wave more than three feet high, curling over with foam at its summit, and forming a distinct wall. This, then, was the bore. A truly grand and almost awful object it is—its rush might almost be taken as an emblem of velocity, combined with weight and power. The roar that it made was like nothing I had ever heard before . . . and in a few minutes the whole appearance of the river *was altered: not an inch of sand could* be seen anywhere, but instead a vast expanse of water reaching from one side to the other."

The Humber, Solway, Seine and many other rivers throughout the world display a bore at high tides; but not infrequently destructive tidal waves pour in for no obvious cause from the open sea, such as the twenty-foot wave that occurred on the Devon coast in April, 1868. Such a wave is sometimes felt on the west coast of Ireland, where it is known as the "death wave," from the numerous human lives it has swept away.

Death-dealing Tidal Waves

By far the most appalling among these visitations from the sea are the so-called (though miscalled) "tidal" waves set up by severe earthquake shocks or gigantic volcanic eruptions, such as that of Krakatoa in 1883, by which whole cities have been laid waste and thousands of people swept out to sea. An inundation caused by earthquake is, curiously enough, heralded in practically every instance by a withdrawal of the water from the shore, as though it had been sucked away by a gigantic syphon. It may retire for only a few yards or for several miles, leaving shipping high and dry; and then, after an awful interval of minutes or hours, the sea comes thundering back in a great wall, rolling far over the dry land and reducing to fragments everything in its path. Other waves follow the first, until the vast impulse of destruction has spent itself.

Wreckage, living fish, immense rocks, may be carried miles inland by the tidal wave, as well as ships from the open sea. During the Jamaica earthquake of 1692, a British frigate was borne by a huge wave far inland over the houses of Port Royal; and on another occasion a warship was carried half a mile beyond the shore on the coast of Chile. In the disastrous Lisbon shock of 1755, a wave of forty feet appeared on the Tagus; at Cadiz it rose to sixty feet, and created huge seas even round Great Britain, as well as causing the waters of Loch Lomond to rise and fall more than two feet.

Towns Washed into the Sea

South America, the East Indies, the Philippines, have grim memories of these awful waves. Some of Chile's largest towns, including Coquimbo, Concepcion, Iquique and Talcahuano, have at various times been washed into the sea, while the city of Arica has suffered the same fate on at least three occasions. In 1918 Porto Rico fell a victim, having 100 people killed and 300 injured by a great sea wave of seismic origin. Disastrous tidal waves have also washed over the southern shores of Italy, where, owing to a geological fault, severe earthquakes are frequent. In the disturbance of 1783 a wave of twenty feet devastated Calabria; and in the Messina earthquake of December 1908, in which more than 77,000 people perished in the same region, the tidal wave reached a recorded height of nearly forty feet. But for magnitude all these waves are far outrivalled by one which is said to have broken over the earthquake region of Kamchatka, in North-east Asia; it is reputed to have been 210 feet in height.

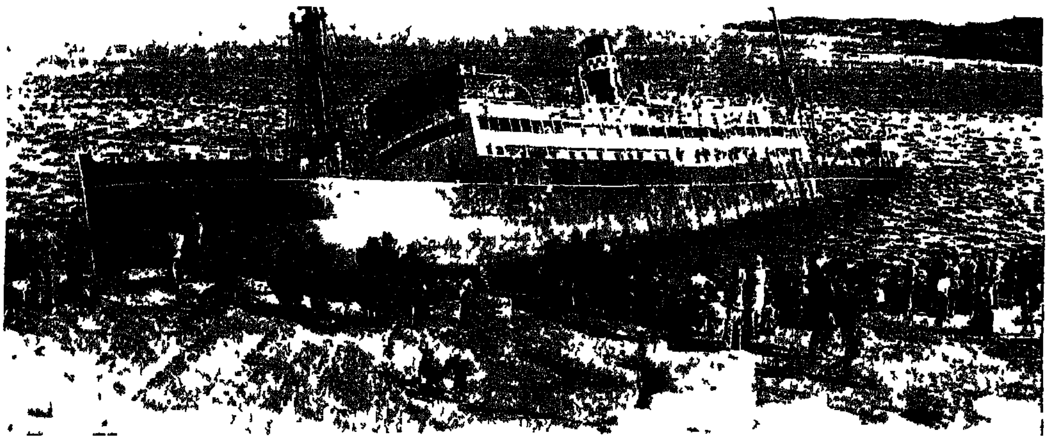
For frequency and severity, the record of tidal wave disasters should go to Japan, the centre of a region of incessant seismic and volcanic activity, which the patient Japanese were at one time wont to ascribe to the restless movements of a huge catfish that lurked beneath the earth. In the last 1,200 years there have been more than 2,000 severe earthquakes in Japan, a great many of them accompanied by enormous sea waves. In the year 684 one of these waves engulfed more than a million acres of land; and in A.D. 869 a great wall of water came up from the sea and slew several thousands of terror-stricken people.

One of the most immense and most deadly waves on record—ninety-three feet in height—was that which followed the Japanese earthquake of 1896, in which no fewer than 27,122 people were crushed by the sea or drawn into its hungry maw, while another 60,000 were rendered homeless. The effect of this wave was distinctly felt at San Francisco, a distance of 4,800 miles across the Pacific. On another occasion, the wash of a "tidal"

wave occurring in South America travelled to Japan, approximately nearly 10,000 miles away.

The Krakatoa Catastrophe

The most tremendous explosion in all history was the eruption—or more truly, bursting—of Krakatoa, the volcanic island in Sunda Strait, Java, in 1883, with a noise that was heard nearly 3,000 miles away. A succession of gigantic sea waves was set in motion, which, after devastating all the neighbouring coasts, set off in a great race round the entire globe. The destruction of life and property by this rushing wall of water was almost beyond conception. More than 36,000 human beings perished and 300 towns and villages in Java and Sumatra were swept away, together with all ships, of whatever size, in the neighbourhood. This tidal wave reached a height of fifty feet, and the force of the explosion impelled it an astonishing distance. It was distinctly felt at Cape Horn, nearly 8,000 miles away, and even reached the English Channel, a distance of 11,000 miles.



Driven aground and sinking within 50 yards of the shore near Sydney, Australia—the 5,000 tons steamer *Malabar* was shortly afterwards battered to pieces by furious seas.

Typhoon, Hurricane and Tornado

Whirled along in the hands of a typhoon or hurricane the sea becomes a weapon of terribly destructive fury, sweeping away in the twinkling of an eye the finest and fairest works of Nature and mankind. Japan, the Philippine Islands, the West Indies, the coasts of Central and South America and many parts of the United States are frequently laid waste by these great storms that come out of the sea. The classic example of a destructive wave raised by a hurricane is the inundation of Galveston, in Texas, U.S.A., on September 8, 1900. Galveston stands partly on a low-lying island in the Gulf of Mexico, exposed to the fury of the West Indian hurricanes. On the fatal day, a tempest of unprecedented violence blew without remission for eighteen hours, reaching a velocity at times of 135 miles an hour. Bridges and telegraph poles were blown away like straws, so that all communication was cut off; and then the terror-stricken citizens, their houses collapsing over their heads, were appalled to see the waters of the Gulf heaped up by the hurricane into enormous waves that came sweeping over the city to complete the scene of horror. In this great storm more than 5,000 people lost their lives, while the damage to property totalled more than £3,000,000 sterling. A vast and costly sea-wall now protects Galveston from a repetition of this terrible disaster.

About Waterspouts

It is a matter of speculation how many out of the long toll of vessels that have put to sea and disappeared for ever from the eyes of men have foundered amid the fury of a typhoon, or have been struck and obliterated by a waterspout. Those who have read "Typhoon," Joseph Conrad's powerful epic of the sea, written with all the knowledge of a practical mariner, will have realized something of the appalling ferocity of these cyclonic storms that rage through the China Seas; but concerning the waterspout there are a great many curious and erroneous ideas.

A waterspout at sea is simply the counter-

part of a tornado on land, and like a tornado originates in an abnormal condition of atmospheric pressure. A heated current of air rises with great rapidity, twisting in a spiral around a centre where the barometric pressure is very low; and the friction of this whirling eddy puts the surrounding air into violent agitation. The waterspout is most frequently encountered in tropical seas and especially in thundery weather. A layer of heavy nimbus clouds extends low over the sea, and from them there descends slowly the characteristic funnel shape of the waterspout. The sea below is seen to be boiling, under the influence of the agitated air and the lowering of pressure; and a cloud of spray is thrown up from the water which unites with the whirling cloud to form a single column. But the waterspout does not suck up a great mass of sea water, as is popularly believed; and, apart from the small quantity of sea spray, the column consists entirely of fresh rainwater, condensed from the heavily charged atmosphere by the lowering of its pressure.

Whirling Wind and Water

Nor does the destructive force of a waterspout arise from the mass of water it contains; it comes almost entirely from the furiously whirling wind in the vicinity, which is just as likely to bring disaster to a ship unlucky enough to fall across its path as is any violent and sudden squall. The column of a waterspout may be twenty or thirty feet in diameter, and it may rise 300 feet above the sea. The duration of the phenomenon is uncertain, but rarely exceeds half an hour. Since it moves with great speed over the sea, in a direction which it is difficult to estimate in advance, this form of whirlwind is highly dangerous to all but the largest ships; but fortunately it is not a very common phenomenon.

Prominent among the terrors of the sea that have been immortalized in fiction is

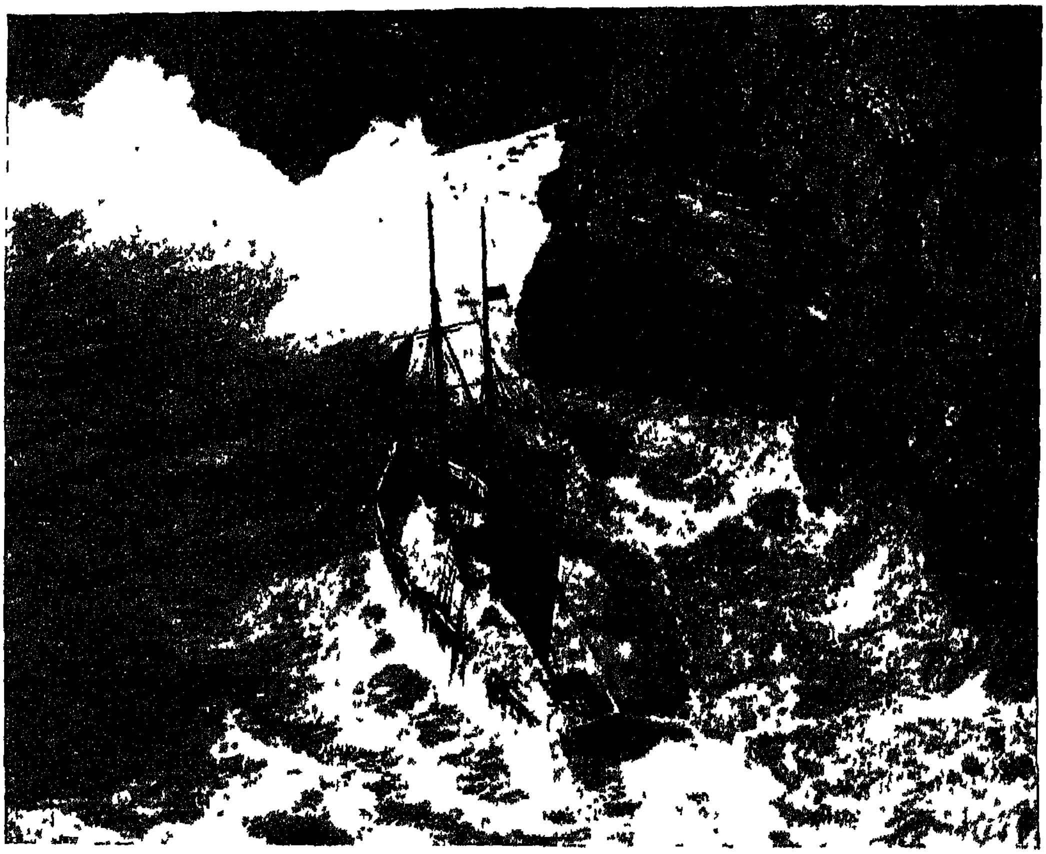


Photo: W. G. Sandy, Truro

On October 30, 1932, the schooner *Sarah Evans* of Appledore was driven ashore at Portreath, Cornwall, in a great gale (*see opposite page*)

the whirlpool, or maelstrom. The archetype of all ocean whirlpools is the celebrated Maelstrom, between two of the Lofoden Islands, off the western coast of Norway; but actually this is not a true whirlpool at all, and its sinister powers have been much exaggerated. The Maelstrom is more correctly described as a tidal race, caused by the sea rushing through the narrow and tortuous channels between the rocks and islands on this weather-beaten coast, and aggravated by a violent cross wind from the north-west, which churns the water into foam. But, although it is constantly navigated, there is no doubt that from time immemorial the Maelstrom has taken a heavy toll of human life, even among the experienced fishermen of the neighbourhood; and it has long had an evil reputation among European seamen. In the year 1557 Master Anthonie Jenkinson, captain of the *Primrose*, bound for Russia, wrote in his log:

"There is between the said Rost Islands and Lofoot a whirle pool called Malestrand, which from halfe ebbe untill halfe flood maketh such a terrible noise that it shaketh the ringes in the doores of the inhabitants houses of the sayd Islands tenne miles off. Also if there commeth any Whale within the current of the same, they make a pitifull crie. Moreover, if great trees be caried into it by force of streams, and after with the ebbe be cast out againe, the ends and boughs of them have bene so beaten that they are like the stalkes of hempe that is bruised."

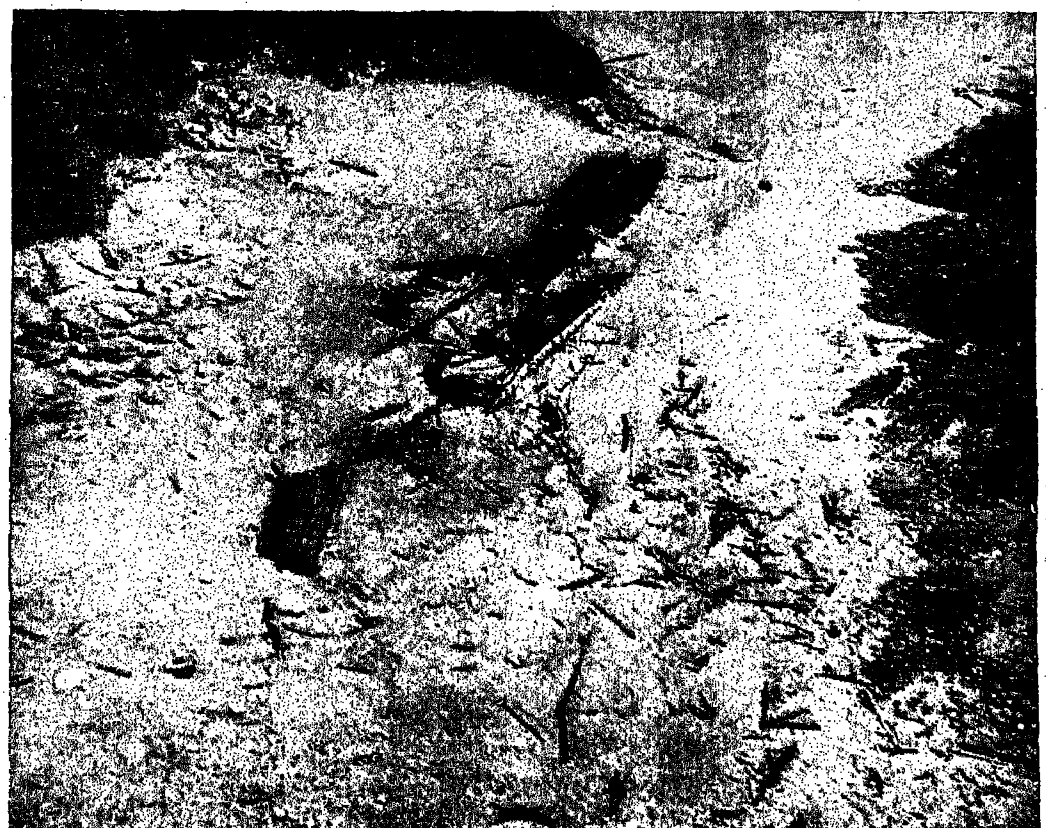


Photo: "Western Morning News"

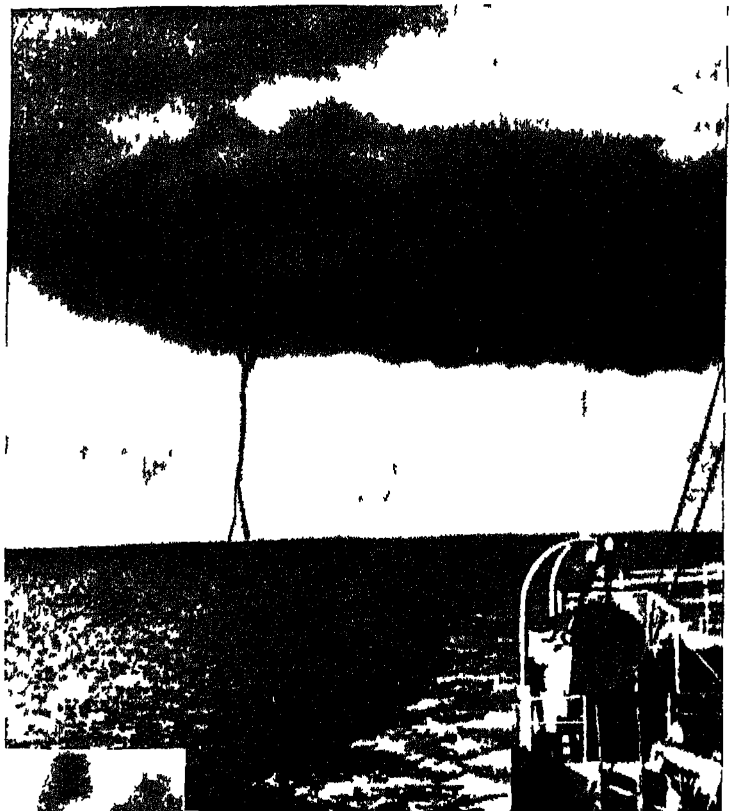
All that was left of the *Sarah Evans* next day, when the mountainous seas had done their work

The Maelstrom in Fiction

Edgar Allan Poe's vigorous and imaginative description of the Maelstrom and its supposed powers of sucking down ships to destruction is well known: . . . "The general surface grew somewhat more smooth, and the whirlpools, one by one, disappeared, while prodigious streaks of foam became apparent where none had been seen before. These streaks, at length, spreading out to a great distance, and entering into combination,

took unto themselves the gyratory motion of the subsided vortices, and seemed to form the germ of another more vast Suddenly—very suddenly—this assumed a distinct and definite existence, in a circle of more than a mile in diameter.

The extreme outer edge of the whirl was represented by a broad belt of gleaming spray, but no particle of this slipped into the mouth of the terrific funnel, whose interior, as far as the eye could fathom it, was a smooth, shining and jet-black wall of water, inclined to the horizon at an angle of some forty-five degrees, speeding dizzily round and round with a swaying and sweltering motion, and send-

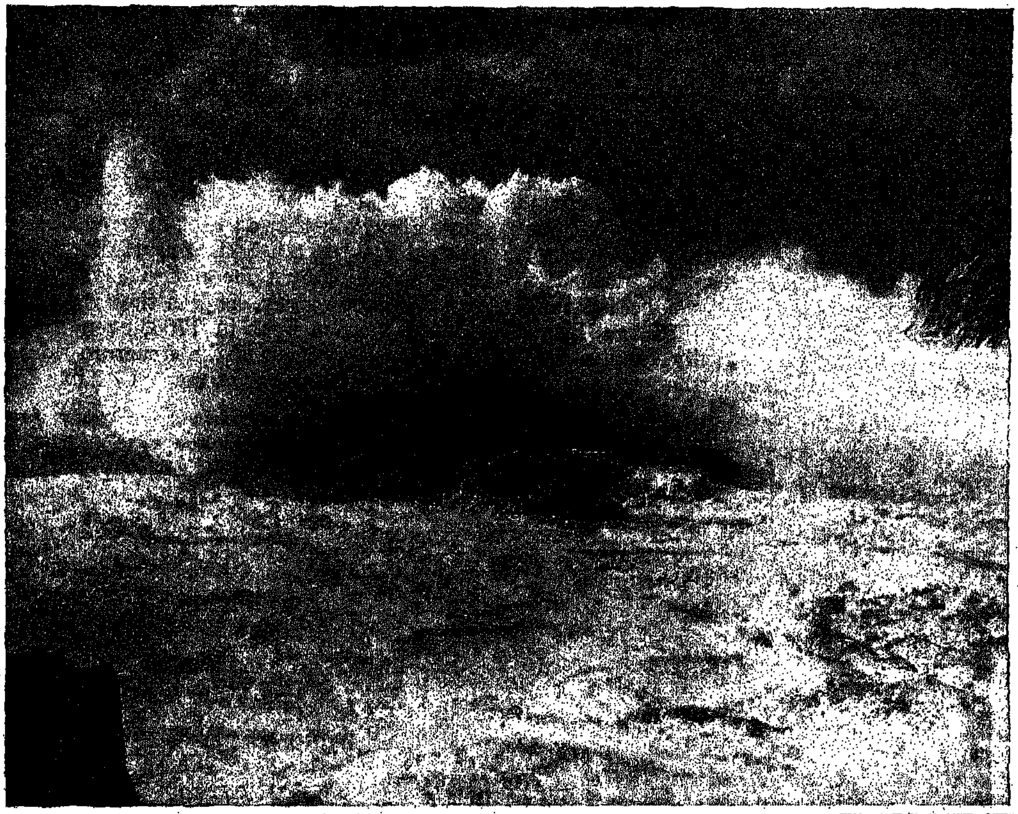


Remarkable photographs of one of Nature's most awe inspiring spectacles. The waterspout is, in effect, a tornado at sea and carries with it similar powers of destruction. The one seen above occurred to the east of Porto Rico, in the West Indies, while that below was photographed in the Black Sea

ing forth to the winds an appalling voice, half shriek, half roar, such as not even the mighty cataract of Niagara ever lifts up in its agony to Heaven."

Although it would be very difficult to exaggerate the actual danger of the Maelstrom under unfavourable conditions of tide and wind, it is needless to remark that the dreadful suctorial powers with which it has been credited are quite fabulous. A similar remark applies to the classical Charybdis of the Strait of Messina, which, according to Homeric legend, was believed to suck down the waters of the ocean thrice a day and cast them up again. Actually Charybdis, like the Maelstrom, is a powerful tidal current.

A true whirlpool can be seen at Corrievreckan, off the island of Jura, in the Inner Hebrides. Here the tides from the mainland of Argyll, on the east, and from the neighbouring Isle of Islay, on the south-



west, collide near a lofty, submerged column of rock, round which they swirl with a rapid vortical movement of about thirteen miles an hour, which is greatly accelerated in high winds. Other true whirlpools are to be found among the Orkney Islands, all of them caused by the meeting of opposing currents.

Periodically the fury of the sea presents mankind with a formidable bill for settlement: the upkeep of lighthouses, breakwaters, harbours and safety devices, and the loss of shipping and merchandise at sea entail an expenditure that never ceases; while the tribute of human life exacted regularly by the sea appals and sickens the imagination.

The mad fury of the sea during a great gale is a sight to admire and marvel at—if the spectator be in a place of safety

Waves, which are the teeth and claws of the ocean, are raised almost entirely by the wind; and in heavy gales they may exert a force of several tons to the square foot. In the open sea of the Bay of Biscay, waves may be lifted to a height of more than twenty feet, and in the open Atlantic to as much as forty feet; while in the more exposed parts of the Pacific a height of sixty feet has been known. On breaking against a large obstacle, waves may be dashed to tremendous heights. On one occasion the five hundredweight fog-bell of the Bishop Rock lighthouse, in the Scilly Islands, fixed a hundred feet above the water, was washed away, together with the flagstaff and ladder; and in Smeaton's celebrated Eddystone Tower the stones forming the cornice of the lofty lantern gallery were frequently lifted from their bed by heavy waves.

On the exposed headlands of the Pentland Firth, according to Sir Archibald Geikie, the geologist, the waves have at times run clean over the cliffs, which have a vertical height of 200 feet, depositing stones, seaweed and fragments of wreckage on the summit as evidence of their assault. Here, too, they have bodily torn up large rocks, reaching eight and a half tons in weight, which they have heaped at a height of more than sixty feet above high-water mark.

The force exerted by sea waves in severe storms is almost incredible. At the lighthouse on the Dhu Heartach Rock, off the western coast of Scotland, for example, stones with a total weight of twenty-eight tons, fitted together and set in cement, were washed away at a height of nearly forty feet. It is not unknown for a lighthouse to be entirely swept away, as was the fate of the first Eddystone light in 1703, even though the first twenty feet of the structure were of solid stone. Enormous masses of masonry in sea-walls and breakwaters have been frequently displaced or overturned. In 1898, during a terrific storm, a part of the stone breakwater at Peterhead weighing 3,300 tons was moved several inches; from the summit of another breakwater stones weighing nearly thirty tons apiece have been flung down like ninepins.

The terrific battering of heavy waves in rough weather is well-nigh irresistible; huge masses of concrete and masonry are cracked asunder as if by high explosives Here is a stout sea-wall at Overstrand, near Cromer, after a series of bouts with the sea

Storm damage is not confined to the battering force of heavy seas, for almost as destructive is the tremendous drag exerted by a spent and recoiling wave upon the shore or breakwater. In heavy storms, millions of tons of beach may be removed by recoiling waves, and the rubble substructure of

expensive breakwaters may be loosened and washed away, necessitating incessant replacement and repairs.

More serious, because more insidious and absolutely unremitting in its destructiveness, is the slow but steady consumption of the coastland by the sea. Sometimes this can be remedied, and the lost land won back again after great expense and toil; but more often it is swallowed for ever by the hungry waves, though elsewhere a desolate beach or a barren mud-flat may be yielded up as though in an ironical exchange.

In Europe, by far the worst sufferer from coast erosion is Holland, whose history for many centuries past has been a tale of one long and ceaseless fight with the sea. The annals of the Netherlands are full of appalling catastrophes, whose regularity makes them monotonous reading. The records at least go back as far as the 6th century, when Friesland was inundated by the sea. In 1277 thirty villages were destroyed, and it was at about this time that an enormous inrush of the ocean created the 2,000 square miles of the Zuider Zee, where formally had been a small inland lake; on this occasion more than 80,000 persons perished. In the year 1421 seventy-two villages and more than 100,000 human lives fell a prey to the ocean, while a vast tract of fertile land was transformed into useless marshes and reed-beds.

The year 1532 saw the inundation of South Beveland, when 3,000 people perished at once; and less than half a century later 20,000 lives were lost by a flood in Friesland. On this occasion Amsterdam itself was inundated. The remaining centuries also contribute their toll of disasters in full measure.

Holland is so low-lying that a great part of the substratum of the whole country is perpetually waterlogged, even in the largest cities. As Niebuhr succinctly remarked: "The real grandeur of the architecture of Amsterdam lies underground, in the shape of the numberless piles on which the city is built." The Stadthaus alone, for example, rests upon 14,000 piles.

It is only by maintaining an intricate system of dikes, dams and sand-dunes held together by long-rooted grass that the Dutch prevent their country from being washed away into the North Sea. Two thousand years of bitter experience have made them specialists in this branch of engineering, and the latest and most ambitious fruit of their labour is the enclosing of the Zuider Zee by an enormous dam, and the draining of this great area to form arable land. The estimated total cost of this undertaking—the largest ever attempted—was equivalent to £45,000,000 sterling. In 1932 the main dam, begun twelve years before, was completed; it is eighteen miles in length. The water was then pumped out, and 553,000 acres of arable land were added to the soil of Holland. The successful execution of this gallant project is one of man's most signal, though rare, victories in his unequal struggle with the ravenous ocean.

Protecting the land against being eaten away by the sea: a sea-wall in the course of construction at Rottingdean

The neighbouring coasts of Europe have suffered severely from erosion. Jutland, Denmark, Belgium, Brittany, the Channel Islands have all been eaten away steadily by the sea, and the loss still proceeds. In the 9th century Heligoland had a circuit of 120 miles, compared with barely three miles at present. The small island of Nordstrand, off Schleswig-Holstein, and the adjacent islets are the sole remaining traces of a large and prosperous tract of land that in 1634 sank beneath an inrush of the sea, which swept away 6,000 people and their homes.

The erosion of our own fair coastline by the waves presents a melancholy picture. The east coast suffers most, for here the land is low-lying, or is of so soft a nature that it is easily eroded, sometimes at the rate of two or three feet in a year. A map of the eastern and southern coasts of England of only a few centuries ago presents a very different appearance from one of the present day. In Norfolk alone, the old site of Cromer lies buried far out to sea; Shipden, one of the most important seaports of mediæval England and celebrated for its large and handsome church, fell into the sea—church, docks and all—in the reign of Henry IV. Many villages in the same neighbourhood, once large and flourishing, have been claimed by the sea and have left behind but the memories of their names. A little over a century ago, Sir Charles Lyell, the eminent geologist, drew public attention to the rapid devouring of Sheringham and the neighbouring cliffs, which proceeds at the rate of at least a yard in a year. At one part of Sheringham harbour there was at this time a depth of twenty feet of water; only forty-eight years previously a fifty-foot cliff, surmounted by dwellings, had stood on the same spot.

The Fate of Dunwich

The coast of Suffolk has a history more dismal still. Aldeburgh, for instance, stood at one time more than half a mile out to sea, and Easton Bavent, once the most easterly point of England, has been shouldered more than two miles inland during the last century and a half. Southwold has similarly retired a mile, and Sole Bay has ceased to exist. The once large and powerful seaport of Dunwich is now commemorated only by a small and shrunken village, lying far away from the spot where the waves of the North Sea roll over the sunken houses and churches of the old port.

Photo: American Colony, Jerusalem

Not waves of the sea, but waves of sand rolling inland and encroaching on arable land in Palestine

The fate of Dunwich is one to make the reader pause and think. In Saxon days it was a great military and commercial centre and the capital of the kings of East Anglia; and in the reign of Henry II it boasted a royal and an episcopal palace, a mint and more than fifty churches and religious buildings. About this time it was the commercial and cultural centre of East Anglia; its markets were famous, its beautiful buildings renowned, and its sea trade to distant parts of Europe was a byword among merchants and mariners. But already

its fate was sealed; for a long struggle had to be waged with the rapacious sea, whose demands grew steadily more insistent. In 1347 more than 400 houses, with many

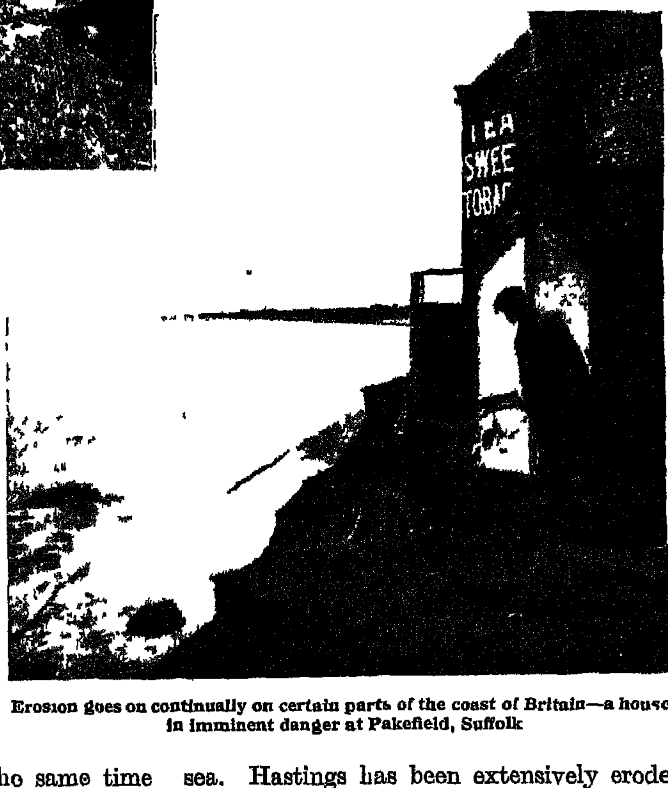
Seats and shelters suspended in mid-air on the cliffs of the Isle of Wight

shops and windmills, were engulfed; and thereafter the destruction proceeded so rapidly that by the middle of the 16th century less than a quarter of the proud old city remained.

In 1677 the sea reached the market-place, and twenty-five years later St. Peter's church had to be abandoned. It was in vain that the despairing citizens gathered on the cliffs and called down curses on the ruthless sea. By the end of 1739 the last scene in this long tragedy was enacted and the small portion of Dunwich that still remained was swept away for ever by the great waves that at the same time reduced the forty-foot cliffs to the level of the sea. As the churchyards successively fell into the ocean, the graves were rudely emptied of their contents, so that the bones of departed citizens of Dunwich could be seen scattered about the seashore. Practically the sole remaining relic of this once large and wealthy port was the cracked and battered shell of the church of All Saints, which for years hung poised on the very edge of the cliff, as if patiently awaiting its fate.

Towns the Sea has Taken

A large part of Essex has likewise disappeared beneath the waves; while across the estuary of the Thames the two upstanding spires of a derelict church mark the last traces of Reculver, once a Roman station and in the Middle Ages a considerable town, which has long been covered by the sea. Folkestone, Dover, Hythe, and all the coast between have undergone considerable erosion, while the whole of Old Winchelsea, a large and wealthy seaport, and the spacious Dimsdale Forest near by, were on February 4, 1287, submerged beneath a terrible onslaught of the waves and now lie buried far out to



Erosion goes on continually on certain parts of the coast of Britain—a house in imminent danger at Pakefield, Suffolk

sea. Hastings has been extensively eroded through the centuries, and the old town rests beneath the Channel.

The Goodwin sands, as is well known, perpetuate the memory of the vast estate of Earl Godwin, father of King Harold. The whole of this great area, with its parkland,

cattle, and grazing sheep and deer sank beneath the waves in 1099, to be transformed into the well-known perilous line of shoals, six miles from the present coast of Kent.

The remaining stretches of our lost coastline are too numerous to be mentioned in detail. Selsey, with its cathedral, bishop's palace and its great deer park; a goodly part of old Brighton; the ancient borough of Shoreham; a great part of the Isle of Wight; the flourishing port of Ravenspur in Yorkshire, where Henry of Bolingbroke landed in 1399 during the bold bid for power that was to make him Henry IV—these are among the most notable portions of England that have found a watery grave. Fuller information concerning them is admirably set forth in Mr. Beckles Willson's "Lost England."

Draining the Fens

By far the greater portion of our departed coasts is lost to us for ever, but in some districts, notably in the Fens—inundated ages ago by a sea-quake—the skill and labour of successive engineers, from the time of the Romans onwards, have wrested many acres of arable land from the hungry maw of the sea. Seventy thousand acres have been reclaimed from the Wash, and a useless and pestilential district has been made profitable and healthy. During the draining of this vast marshland many interesting discoveries have from time to time been made, which prove that at no dim period this was a dry, fertile and pleasant tract of country. Large numbers of oaks and fir trees, many of them being of considerable size; hazel bushes with their nuts still sound and firm; the antlers of stags that once roamed through the sunken forest; weapons, canoes, and even a blacksmith's forge with its tools and horseshoes, buried sixteen feet deep beneath the silt, offer silent testimony to the everyday activities that were rudely interrupted by the sudden inflowing of the sea.

Models to aid the Engineer

Science has lent the modern engineer many useful allies in his unceasing struggle with the sea. One of the most valuable aids to present-day land reclamation is a tidal model of the area that is being reclaimed, and of these models the largest in existence was completed at Cambridge in 1935. It is an exact representation of the mouth of the Ouse and the whole of the Wash, covering forty miles of fenland on a scale of twenty-five inches to the mile. Housed in a large building of its own and operated by electricity, the model works automatically, the tides of the Wash being faithfully represented in miniature by the ebb and flow of water operated by a twelve-ton plunger. The natural tides of an entire year can in this model be compressed into the space of twenty-seven hours, and the detailed information thereby afforded has already proved of inestimable value in helping to solve the difficult problems of land reclamation in the Fens.

CHAPTER VI

SAFETY AT SEA BY NIGHT AND DAY

THE sea can be very beautiful, but it can also provide the most terrifying sight imaginable. Anyone who has experienced a storm at sea needs not to be reminded of the awe-inspiring horror of it, and those who have watched seemingly insignificant little ships battling their way into harbour against mountainous waves, tearing gale and lashing rain must have felt proud of the magnificent courage of these men "who go down to the sea in ships." Theirs is a precarious existence requiring the very highest type of courage and it is fitting that a number of inventors and engineers have devoted part or all their lives to making the sea safe for travel night and day. Of course no one has yet learned to control the wind and the waves; but, in the light of modern knowledge, everything has been done to ensure the greatest degree of safety for those who cross the ocean either on business or pleasure bent.

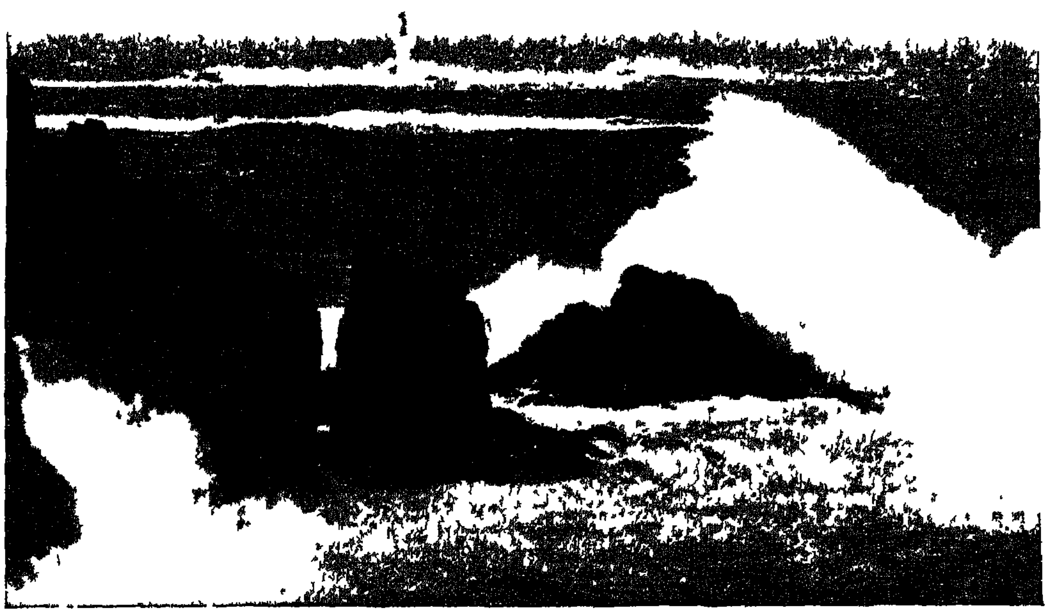
The Mariner's Beacons

Among the many contrivances which have been evolved to ensure safe travelling at sea are lighthouses. As a rule most people regard a lighthouse simply as one of those tall towers that stand isolated among a pile of jagged rocks as at Beachy Head, near Eastbourne; Corbière, Jersey; and Eddystone, off the Devonshire coast, but the term lighthouse is used more generally and includes lights which are also situated on land and which serve an entirely different purpose.

Lighthouses are divided into certain definite groups which perform specified duties. Occasionally one light in a group will also perform the functions of another group, but most of them are built for one purpose and perform one duty only.

The first group of lights is termed "landfall" or "making" lights, which are so named because they are the first lights that the mariner glimpses when he is approaching land. Landfall lights are generally the most powerful lights that are visible from the sea. Their sole object is to tell navigators that land is near, so they must therefore be strong enough to pierce the darkness at as great a distance as possible, and they must also be situated as high up as possible in order that the curvature of the earth's surface shall not restrict the limit of their range. When speaking of the range of a light, in reference to lighthouses, the term "range" always means the distance at which a light is visible from the sea. This distance depends on three things: the candle-power of the light; the height at which it is placed above sea-level; and the curvature of the earth's surface. A light placed five feet above sea-level can be seen, by a mariner on the deck of a vessel fifteen feet above water, at a distance of seven miles. If the light is twenty-five feet above sea-level he can see it 10·17 miles away; fifty feet above sea-level, 12·55 miles away; 100 feet above sea-level, 15·91 miles away, 500 feet above sea-level, 30·09 miles away; and 1,000 feet above sea-level, 40·72 miles away.

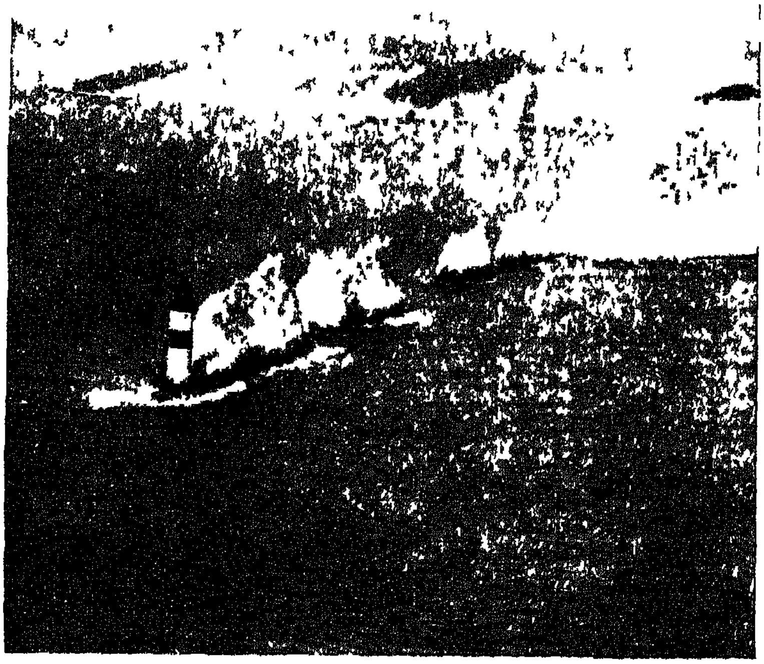
There is, however, one objection to placing a light very high up, and that is the effect of fog. A thick fog very effectively blankets even the most powerful light, and in consequence it is not always practicable to fix a landfall light on a very tall tower, in spite of the theoretical advantage of placing it as high up as possible to increase its range. Fog very often hangs some distance above the sea while the sea itself is quite clear, and a landfall light wrapped round with fog is of very little use. At one time there used to be a light fixed to a tower on Beachy Head, but owing to the prevalence of fogs on this headland, it was very often seriously dimmed and for that reason was superseded by a tower built up from the foot of the cliffs. The range of the Beachy Head light was, of course, very much shortened, but it nevertheless became more effective since henceforth it was nearly always visible.



With huge Atlantic waves dashing almost to the top of it—the Longships lighthouse off the Cornish coast

The Beachy Head light, it should be noted, is not a landfall light but one of another

group which will be mentioned a little later on. The best known landfall light in this country is the Lizard, the name of which appears every day in our newspapers. It is the first light sighted by ships coming towards the south of England from the west and south. Almost as well known is the Fastnet Rock light, which the transatlantic liners "make" as they approach the south coast of Ireland. Others, just as well known



The Needles lighthouse at the western extremity of the Isle of Wight—a view from the air

to mariners but not quite so familiar to stay-at-home Britishers, are: the Ushant light, situated to the north of the Bay of Biscay, and sighted by navigators entering the English Channel from the south; Cape Race, Newfoundland, the signpost to vessels entering the St. Lawrence River; and the Navesink, situated at the entrance to New York Harbour.

A little earlier, candle-power was mentioned as one of the three things on which the range of a light depended. No matter how powerful a light is, however, unless it be sufficiently elevated above sea-level its range is not extended even though it has a high candle-power. For example, the range of the most powerful lamp fixed twenty feet above sea-level cannot exceed 9·57 miles, since beyond that the curvature of the earth's surface hides it from the mariner. On the other hand, it is obvious that if one were to strike a match on a tower twenty feet above sea-level it would not be visible to a sailor nine and a half miles away. The beam of light must be powerful enough to reach that distance—hence the candle-power is one of the primary things on which the range of a light depends.

Warning Lights

The *second group* of lights is "Warning lights" and it is to this type of light that most people refer when they speak of lighthouses. They are erected almost solely in places which are considered to be very dangerous to shipping; hence their name.

The lighthouse is, comparatively speaking, a familiar sight in these days; but, even so, the man or woman who can look upon one of these towers without a sense of wonderment and something of awe must indeed be lacking in the spirit of romance. Few, however, though they may be moved by the isolated magnificence of a lighthouse with its background of jagged rocks and swirling, angry foam, are sufficiently interested to ponder on its origin, the dangers that beset those who built it, or the various mechanical and scientific inventions that have made it of such value to the mariner and to all those who voyage on the seas. Fewer still wonder how it is that this tall structure stands firm and immovable, flashing out its brilliant light during the wildest and most fearful of storms; for it does not seem to occur to them that if the foundations of a lighthouse were built on the same principles as those of the houses we live in, it would not last a month—perhaps not a week.

Some idea of the extent of the task, and the effort and danger involved in the building of a lighthouse, can be understood if we delve a little into the history of the Eddystone Lighthouse. The Eddystone rock is part of an extensive reef of rocks about fourteen miles south-west of Plymouth Harbour. At low water the reef stands out jagged and black, but at high water it is almost entirely covered. The rocks comprising the reef lie in the direct route of coasting vessels and of ships bound for Plymouth Sound; in consequence, without a warning signal on the reef, they would constitute a serious menace to shipping. The first man to attempt to build a lighthouse on Eddystone was Henry Winstanley. The building was begun in 1696 and completed in 1700. The foundation for the superstructure comprised twelve iron bars which were fastened into the solid rock, and on which a solid pillar twelve feet high and fourteen feet in diameter was built. Later this solid structure was raised to a height of twenty feet and was topped by a quaint wooden tower, with open galleries below the light chamber, which was furnished with a weather-vane. The lighthouse stood until 1703, when with Winstanley, who was superintending some necessary repairs, and the light-keepers, the whole edifice was swept away during a terrible storm.

Rudyerd's Lighthouse Destroyed by Fire

John Rudyerd was the next to build a lighthouse at Eddystone, and although it was a vastly superior structure to that of Winstanley's, it was again mainly of wood. This time the lighthouse was destroyed by fire. It had, however, stood the buffetings of the winds and the waves for nearly fifty years.

The third Eddystone lighthouse was constructed by John Smeaton, and in performing this feat Smeaton laid down the principles that underlie the erection of all modern lighthouses. Smeaton's lighthouse has, of course, been improved on, but considering his limited knowledge and the comparatively rudimentary tools he had at his command, it was a very remarkable piece of work. Smeaton recognized—right from the earliest stages, when he was asked to undertake the work—that the foundations of the lighthouse structure were of paramount importance. He determined that the Eddystone should be made absolutely solid with the rock itself; and in order to attain this the living rock was hewn away to accept the foundation stones, which were dovetailed into one another in such a way that they were absolutely immovable.

Each stone was made by hand and numbered; each was cut with extreme accuracy; and each was examined, checked and passed by Smeaton himself before it was allowed to take its place in the lighthouse. The making of the foundations and the laying of the earlier stone courses was a task to dismay even the boldest engineer.

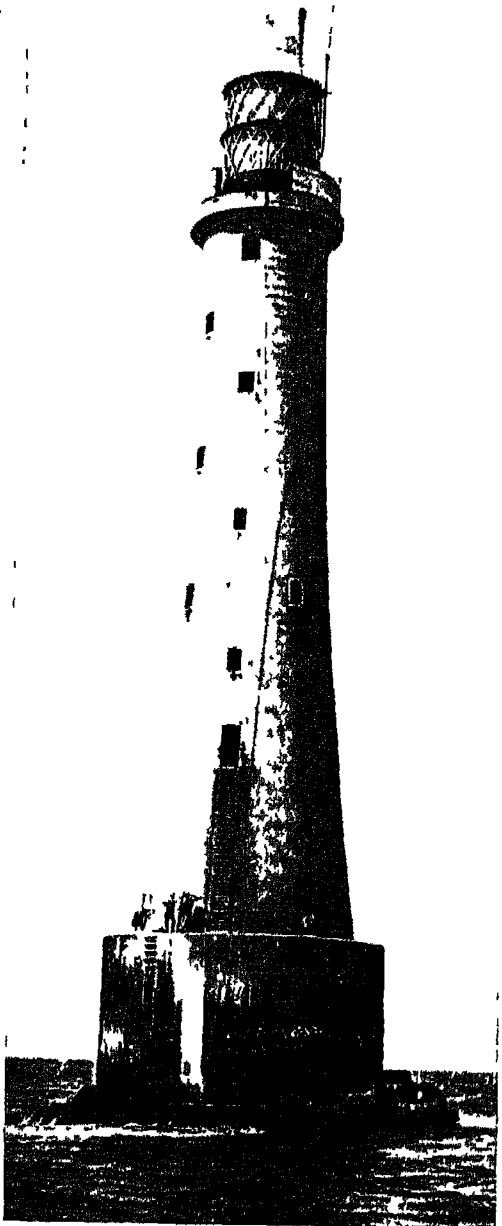
The Wolf Rock lighthouse—18 miles from Penzance—is one of the loneliest and most dangerous of all lighthouses; and relieving the keepers is frequently a task of the greatest difficulty. An ingoing keeper is here seen being hauled on to the lighthouse platform during rough weather

Practically all of it was done by hand, for there were then no mechanical drills for cutting away the rock, and no cement mixing machines for getting the cement to the right consistency; then, too, work on the rocks could only take place when tide and weather conditions were favourable. Only about two hours a day could be devoted to the fixing of the foundations and the earlier courses of the lighthouse, and sometimes for weeks at a time no work at all could be carried out.

Even when work was in progress, there was always the possibility of a sudden storm sweeping up and washing the men to their doom. The foundations were begun on August 3, 1756, and the light first shone forth on October 16, 1759, continuing to do so until 1882. It is a great tribute to Smeaton and his men that his lighthouse proved to be stronger than the rock on which it was built; for when the structure was condemned, it was on account of the rock itself being undermined by the waves, not because of any defect in Smeaton's building. The existing Eddystone lighthouse was built by Sir J. N. Douglass and completed under the supervision of Trinity House in 1882.

Many other lighthouses have as thrilling and romantic a history as the Eddystone; but this narrative serves to show the dangers that have been faced and the ingenuity that has been used to protect the voyager from the perils of the ocean and the rocky coast.

As has been mentioned, some lights are used for two purposes; and among these may be instanced the Fastnet Rock light, off the coast of Cork, and the Bishop Rock light, which is situated between the Lizard and the Scilly Islands. Both these lights are landfall lights, telling the transatlantic mariner that his voyage is nearly over; but they are also warning lights, for they speak of dangerous rocks in the vicinity. Then, too, there are other dual-purpose lighthouses which serve to warn of more than one danger. For example, a lighthouse which serves as a general warning to sailors of dangers in the vicinity may also be used to indicate a dangerous reef or shoal a few miles away—doing this latter job by means of a separate beam of light called a sector. The sector is generally shone from a window below the main light chamber, and is thrown in the direction of the particular danger and over it. The same expedient is used to show a channel between two such dangers, and often it will be found that these sectors are of different colours. Special apparatus has to be installed for sectors, as they must of necessity be fixed lights, arranged at a definite angle so that they indicate exactly where the danger lies.



The Bishop Rock Lighthouse, between the Lizard and the Scilly Islands

There are certain natural conditions and other circumstances which sometimes make it impracticable to build a lighthouse, and then, where danger to the mariner exists, other means of warning must be employed. Among these are lightships—which will be dealt with in a little more detail later—and light-buoys. Both are included in the "warning lights" group, although they are occasionally used for other purposes.

Light-buoys, although warning lights, can also be classed as unwatched or permanent lights since they have no one continually tending them and are often left for considerable periods without attention. As a rule these buoys are situated on small rocks out

at sea, or close in to land on breakwaters. How long they are left unattended depends on the situation, on the kind of fuel used for the light, and on the size of the containers which hold the fuel. Apart from the fuel storage, no matter whether oil, coal or acetylene gas is used, the burners need attending to at certain intervals. Similarly the lenses become covered over with salt from the spray of the waves, and need cleaning.

Buoys lit by acetylene gas could be left for as long as six and in some cases even twelve months, but such a long time is seldom allowed to pass without some attention being given them. As a rule light-buoys are never placed in positions which are too remote for some sort of supervision, because in a thick fog such a buoy might quite easily be run down by a vessel. Should this occur, and the event not be known or be reported, the absence of the light might prove a serious danger to shipping.

The third type of light is the "coasting" light, and it is used as a signpost for the mariner. The Beachy Head light is one of this type. These lights do not need to be so powerful as either the landfall or warning lights, since the navigator who has once "made" the coast is never at any great distance from the coasting lights. He needs only to be able to distinguish between them to find his position as he passes up and down the channel. "But," one might ask, "how can a sailor tell one light from another?" The answer is a simple one: they are all different. The sailor does not have to be a magician to distinguish between them, but he does need to possess a good memory. Each light is made to differ from the next by means of flashes. Although the system employed is not based on the Morse code, these lights act on something of the same principle in that the difference between them consists entirely of variation in the length of the flashes that are given out, and of the intervals of darkness between the flashes. Thus the navigator who knows the system thoroughly is able to pick his way up and down the coast at night as easily as if it were broad daylight.

Light "Characters"

Each light is distinguished by what is termed its "character"—that is, its appearance as viewed by someone looking at it from a distance. Anyone who has sailed through the English Channel, which has an exceptionally well-lighted coastline, will realize how essential it is for the coasting lights to have differing characters; even the lighthouses are comparatively close to each other, and some method of distinguishing between them is essential. The character of a light is determined by the length of the flashes and of the intervals between; and, in some cases, by the fact that the light is a fixed light. For example, one might be a "fixed white," another a "fixed red," and another a single-flashing.

The Group Flashing System

In the case of flashing lights what is called the group-flashing system is used in this country, and in order to understand the basic idea it is necessary to gain some knowledge of the lighting apparatus used in lighthouses. The type of light most favoured to-day is that obtained from a vapour oil lamp which uses incandescent mantles. In the case of lighthouses built on the mainland there is of course no need for special apparatus, since the local gas company is able to supply the means of illumination. In lighthouses such as the Eddystone, however, oil has to be used. It is stored in steel tanks, from which it is forced by air pressure through a small copper pipe into a vaporizing tube on the burner, which is heated from the outside. Passage through this tube turns the oil into a gas, which then passes through a burner, is ignited, and heats the mantle.

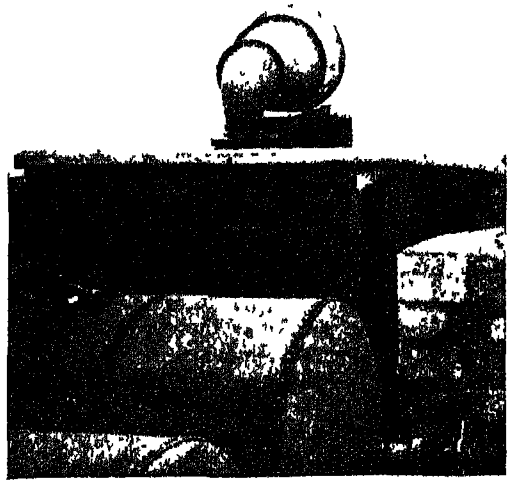
This method of illumination is simple, efficient and economical. Efficiency is, of course, the paramount necessity of a warning light; but in view of the fact that many lighthouses are isolated, simplicity of operation is almost as essential, while economy is also highly desirable. So economical is this type of lamp that only just over two pints of oil are required every hour to feed a 2,400 candle-power light. Electric light, by the way, is not used a great deal in lighthouses on account of the bluish colour of the arc light and the fact that blue light rays are more easily bent than others. This peculiarity of blue rays makes them less able to penetrate fog than a reddish-coloured light.

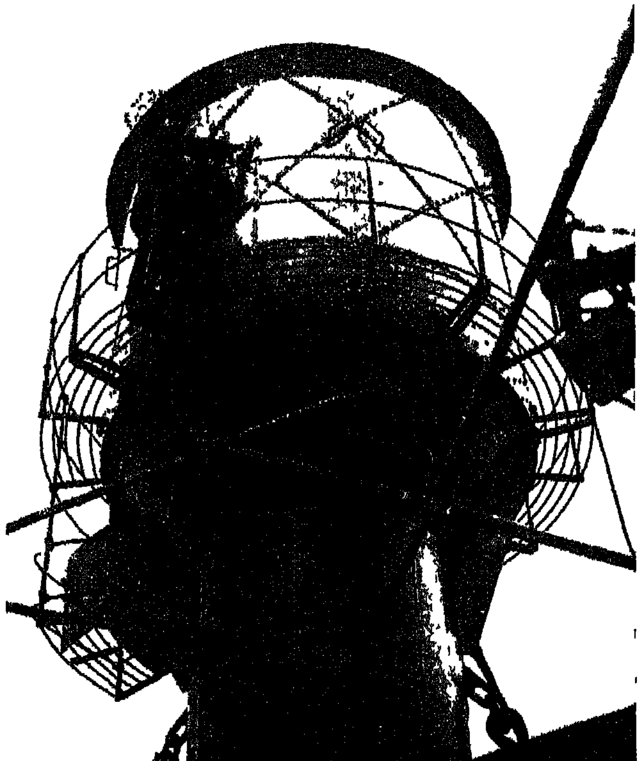
Most of the biggest lighthouses have a revolving light apparatus, in which the lenses are composed of prisms and are built up into what are called panels. Each panel forms a huge bull's-eye lens and is so arranged that practically all the light from the burner is utilized. It is the skill which scientists and inventors have used in avoiding any loss of light from these burners that makes the panels such wonderful pieces of work. They

are mounted on a table which revolves round the burner in the centre of its pedestal, and thus as the panels revolve the light is thrown out to sea in a series of flashes. One of the most remarkable features of this apparatus is that although the revolving panels weigh several tons they can be moved with the touch of a finger, for the revolving table floats on mercury.

In the group-flashing system the panels are so arranged that a number of flashes can be given in rapid succession, and be followed by a varying interval of darkness, before another series of flashes occurs. The number of flashes is generally limited to between two and six and although a still larger number could be produced, it has not been found necessary, as the coasting lights and warning lights can be distinguished without.

Two other types of lights need only a brief mention; they are "leading lights," which show the line of a channel or the entrance to a harbour, and "port-lights," which are used to mark the end of piers.





Cleaning the lantern of the "Outer Dowsing" lightship, 28 miles off Grimsby. *Top:* Fog horn at Fort Doyle, Guernsey

Lightships. — Lightships are moored at places, such as sandbanks, where it would be impossible or extremely difficult to build a lighthouse. The Goodwin Lightship on the Goodwin Sands immediately leaps to the mind, with the Sandettie, situated off Dunkirk and the Nore. A lightship, of course, is simply a ship specially designed to suit the conditions of the sea where it is moored, and on which a light is shown from the top of a mast. It is actually a small lighthouse and nowadays the lighting apparatus resembles very closely that obtaining in the latter.

Fog Sirens.—Men have worked effectively to make the sea safer for voyagers, with warning lights and beacons; but by far the greatest danger lies in fogs which hide the various lights from mariners and shut in ships both by daylight and by darkness with a veil well-nigh impenetrable. Against fog there was formerly only one defence—the sound-signal; but to-day the seafarer has two others—the wireless directional beam sent out from lighthouses, lightships and shore stations, and the wonderful

fog-piercing infra-red ray apparatus. The sound-signal is used in various forms, the most favoured being the siren. It consists of a disk, with a number of slits in it, which fits against a similar stationary disk and can be rotated at a very high speed. While it is revolving compressed air is forced through the slits, producing a note of controllable pitch which is capable of carrying a considerable distance.

A similar type of siren consists of a cylinder which has circular slits in it, and when the cylinder is given a reciprocating motion, by means of compressed air, sound is produced. Most lighthouses are provided with sirens of the above types Other sound-producing apparatus includes one for making reed signals, which consists of a metal tongue that closes over the end of a pipe and under pressure is caused to vibrate and produce a note not dissimilar to that of an organ; trumpets worked on the same principle as the cylinder type of siren, and bells, operated by means of a clockwork mechanism

So far our narrative has dealt with the efforts and contrivances that have been made and employed to prevent ships going astray and coming to grief on reefs or shoals, but in spite of all man's ingenuity calamities still occur and lives are imperilled or lost around our coastline.

As far back as 1784 a London coachbuilder named Lionel Lukin began to experiment in an attempt to produce a boat which would never sink. His object was not primarily to make a boat to save lives, but nevertheless for some years his was used for that purpose. Five years later a boat deliberately designed for the purpose of life-saving was launched at South Shields. That boat, called *The Original*, was partly designed by William Wouldhave, the inventor or discoverer of the self-righting principle which is the basis of many lifeboats. This first lifeboat saved hundreds of lives before it was eventually destroyed; but by then it had served its purpose in that a movement for building lifeboats had begun. Henry Greathead by the end of 1803 had built thirty-one oar-propelled boats especially for the purpose of saving lives, and in 1807 Lukin designed the first sailing lifeboat.

It was in 1824, however, that life-saving at sea became a national undertaking, for in that year the Royal National Lifeboat Institution was founded. The Institution at once organized life-saving on sound and business-like lines; at the same time caring for those who risked their lives in the service of their fellow-men, and for the dependants bereaved by such noble sacrifice. Buildings, boats and accessories came under thorough supervision; rewards were given to men who dared all to help others; compensation paid to those injured in the service.

Courtesy of the Royal National Lifeboat Institution

A remarkable photograph of the launch of a motor lifeboat in a heavy sea

After the first enthusiasm for an institution which had been founded for such a noble service, interest in the work began to wane, and the Institution passed through some very difficult periods until at last a terrible disaster at sea awakened the people of Britain to the importance of the work

being carried out and the urgent need of support.

The Self-righting Lifeboat

Under the presidency of the fourth Duke of Northumberland this excellent Institution received a tremendous impetus, and from thence onward it has progressed steadily. As a result of his practical encouragement a self-righting lifeboat was designed by a man named James Beeching, and this boat, with but slight alterations, is the type in use to-day.

Everyone has doubtless seen a lifeboat that it is fitted with air-cases which, even if the boat is severely damaged, operate effectively to sustain it. The ability to free itself from water is due to the provision of relieving valves or scuppers, through which the water pours out of the vessel as rapidly as the waves fill it. A lifeboat is divided into from seven to fourteen water-tight compartments, and has from 70 to 160 air-cases. The latter are the cause of the extreme buoyancy and make it possible for the vessel to carry on with its rescue work even if twenty holes are knocked into each side. It is, in fact, almost unsinkable.

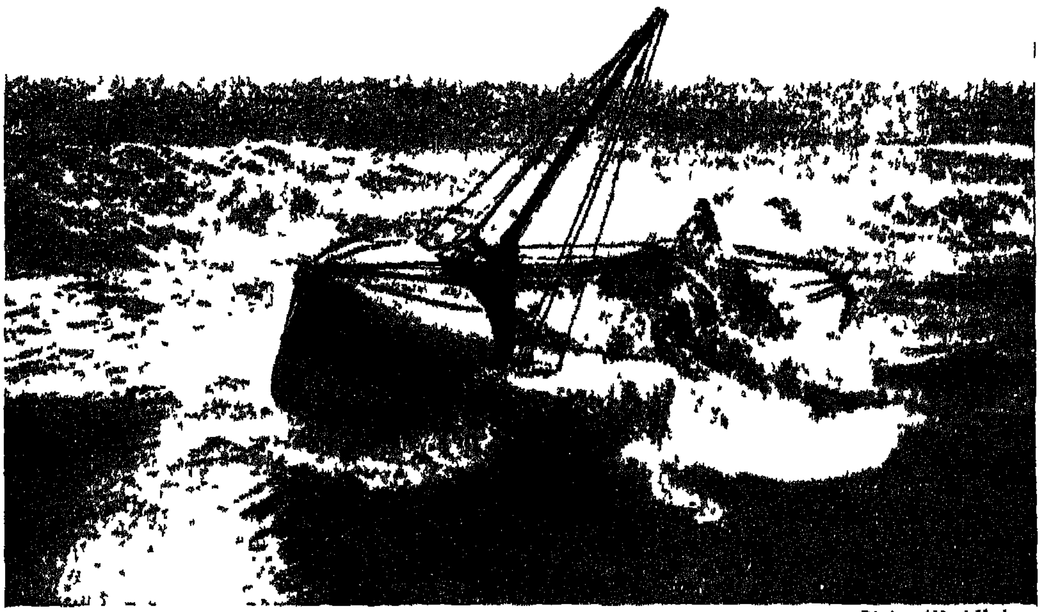


Photo: Alfred Hudson

One of the crew of the Bridlington motor lifeboat being hauled in after being washed overboard while the boat was returning home. All part of the day's work in the hazardous lifeboat service

and has been struck by the fact that although it is so small a boat, yet it seems able to ride a storm better than larger and more powerful vessels. The reason for this ability, as it were, to flaunt the power of Nature, is that in spite of its size the lifeboat has great strength, great buoyancy and the ability to free itself from the water with which it becomes deluged when waves break over it. In building lifeboats the makers are allowed to use only the best woods, and timber which is thoroughly seasoned and very carefully selected. Its buoyancy is due partly to clever designing and partly to the fact

The self-righting lifeboat—not all the Royal Institution's boats are of this type—with its complete equipment, its sails set and all its crew on board, will right itself if it is completely capsized, and free itself of water in twenty-five seconds. This is on account of its heavy keel and its two air-chambers, situated one at each end of the boat. Though these air-chambers make it so easy for the lifeboat to right itself on being capsized, there is another side to the medal: in heavy weather they exhibit a tendency to make the boat perform the complete cycle too readily, i.e. to turn

completely over and come upright again. For this reason another type, one which cannot right itself, has been evolved by the Institution, whose fleet is composed half of the first type and half of the second. The non-self-righting type is much more stable, has greater speed and has greater buoyancy. The lifeboatmen themselves are the ones who choose which type of boat they will adopt, the Institution never giving any crew a lifeboat unless they express themselves satisfied with her.

There were, at one time, a few steam lifeboats in the Institution's fleet, the last being withdrawn in 1928, but it was not until the arrival of the internal combustion engine that the lifeboat found the motive power suited to its needs. The work of adapting the petrol-engine to the requirements of the lifeboat was by no means easy, for the essential features of the lifeboat had to be retained, and at the same time the engine had to be almost automatic in its method of working: even if the boat were on end, it would still have to feed itself with oil and petrol; it could not be given much attention while rescue work was in progress; and, because the lifeboatmen were simple folk, its controls must also be simplicity itself. Nevertheless, as in other branches of engineering, the builders solved the difficulties and as a result, to-day, no fewer than 124 motor lifeboats are in service round the coasts of Great Britain and Ireland.

Here is the record of just one of the rescues attempted by a lifeboat in the service of the English section of the Royal National Lifeboat Institution.

A Tale of Heroism

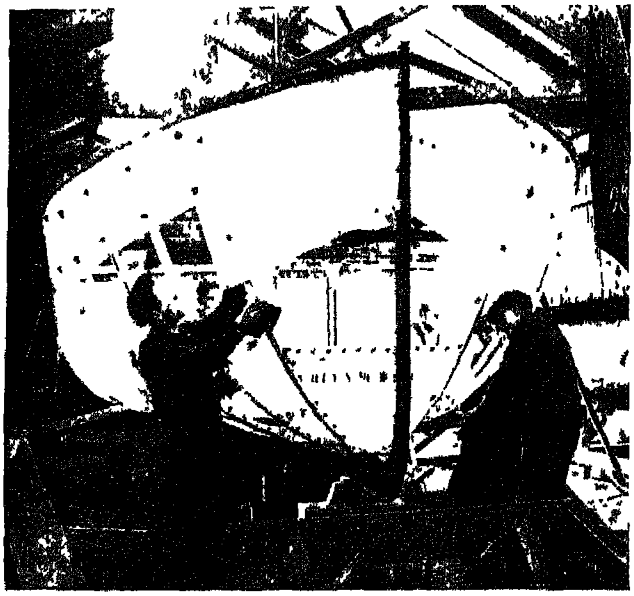
With practically no warning, on December 13, 1933, an easterly gale swept across England, and a Dover barge named *Sepoy* was driven ashore at Cromer at eight o'clock in the morning. At four o'clock that morning the Cromer motor lifeboat had gone to the assistance of another wreck eleven miles away, so the pulling and sailing lifeboat was put into commission. By the aid of volunteers the boat was launched, only to be hurled, broadside-on. to the beach again. After being launched a second time, her crew kept her afloat for twenty minutes, when again she was driven back on to the shore. Meanwhile the crew of two on the barge had been forced to take to the rigging as the waves were sweeping over their craft. Again the lifeboat was launched, and this time although the boat was able to make the wreck it could not get alongside it and was driven to shore again.

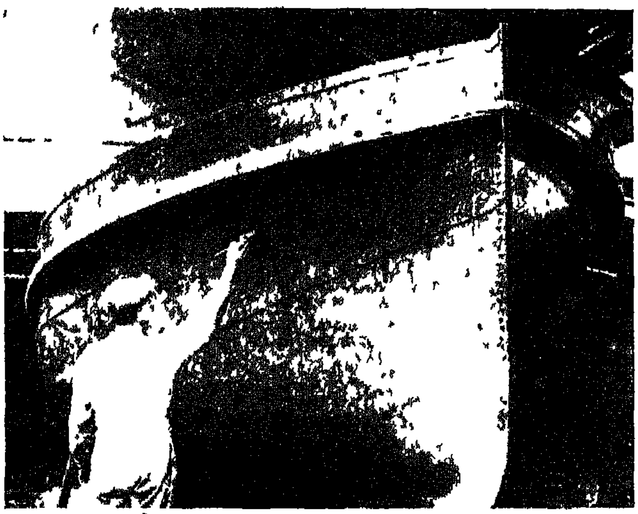
It was now two o'clock in the afternoon and with the rising tide the men on the barge had had to climb higher up the rigging. It was known that the motor lifeboat would make for Gorleston. A message had been sent there, and the Gorleston motor lifeboat went out with it. Eight miles out, the two lifeboats met. In spite of the fact that it had already been out for eight hours, the Cromer lifeboat put about to go to the rescue of the two men on the *Sepoy*. At three o'clock that afternoon the motor lifeboat came in sight of the anxiously waiting crowd which by then had almost given up hope of the two men being saved, for the gale was at its worst and the barge was being continually swept by heavy seas.

Courtesy of the Royal National Lifeboat Institution

Inside the engine-room of a motor lifeboat. The two high-speed submersible engines—each of 35 h.p.—give the boat a speed of 7½ knots

Time and again the coxswain of the lifeboat tried to get alongside the barge, but each time the boat was driven past the wreck. At last, however, the coxswain got his craft near enough for them to throw a grapnel into the rigging, but before they could make use of their advantage a big sea flung the lifeboat against the wreck and holed her side; the grapnel-line parted. Realizing that it might now be a matter of minutes before the exhausted men collapsed and fell from the rigging, the coxswain decided to make no further attempt to get alongside the barge. Instead, he drove the lifeboat on top of the barge and stove in the bulwarks with his bows. The boat was held there just long enough for three of the crew to get hold of one of the men and get him aboard, when the lifeboat was washed away again; but again the coxswain drove his vessel into the wreck and the second man was dragged to safety. The lifeboat was then turned for safety, while willing hands tended to the rescued.





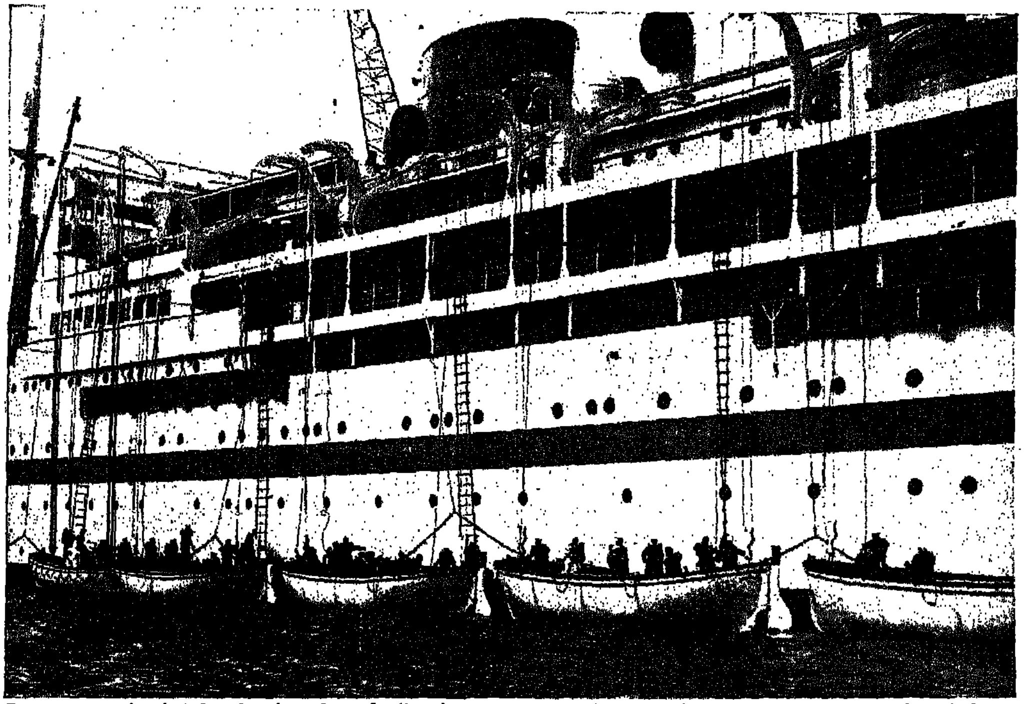
Efficient lifeboats may mean the difference between life and death to passengers and crew of a liner. The 24 steel lifeboats of the *Queen Mary*—here seen during construction—are fire-proof and unsinkable, and are fitted with Diesel engines which will function in all weathers. Each lifeboat will accommodate 154 passengers

That story is a typical one of difficulties encountered and surmounted, and typical, too, of the heroism shown by the members of the Lifeboat Institution, which since it was founded has saved 64,596 lives and records an average of eleven lives saved per week for the past 112 years.

When the Lifeboat Institution was founded it established rocket apparatus for projecting lines to wrecks from the shore; but the Coastguard Service also was instructed that if a wreck took place, every man within reasonable distance was to do his utmost to assist in the rescue work. At the same time a full set of "apparatus for saving life" was issued by the Crown; and later, in 1864, the Board of Trade took over the administration of this apparatus.

Nowadays the life-saving apparatus is stored in a convenient spot and when required is transferred by the best and most rapid means possible to a point close to the scene of the wreck. It can only be used when a wreck occurs close to the shore.

The life-saving apparatus consists in the main of a species of gun from which a rocket, with a line attached, is fired, the object being of course to make the line fall across the stricken vessel. On the land side of the line, and to it, is attached a hawser which, when the seamen on the wreck have made fast their end, enables the rescuers on land to send across a breeches-buoy. The buoy is in effect a lifebelt, and by means of pulleys and lines it is traversed from the shore to the wreck and back again, carrying with it, on its return journey, one of the people from the wrecked vessel.



Every precaution is taken for the safety of a liner's passengers and crew and to prevent confusion and panic in an emergency, lifeboat drill—here seen in progress on S.S. *Dilwara*—is frequently practised

Photo: Hawke, Helston

Bringing the crew of the sailing ship *Adolf Vinnen* safely ashore at the Lizard, by means of the breeches-buoy

CHAPTER VII

MIGHTY WALLS BUILT BY ANIMALS

THE greatest of all the world's builders were not the men who raised the mighty pyramid of Cheops on the shifting sands of Egypt, nor the pious craftsmen who created the mighty cathedrals of mediæval Europe, nor yet those who have called into existence the most splendid buildings of to-day, in all their pride of massive steel and concrete. They who have built on by far the greatest scale are the hundreds of millions of humble, feeble, jelly-like creatures whose ceaseless and united efforts through millenniums of time have formed the coral islands and barrier reefs of tropical seas. Yet the only building materials employed by the industrious coral polyps are their own fragile skeletons, which have been slowly and patiently secreted out of the mineral salts contained in the sea-water in which they live.

The numerous species of coral-building animals belong chiefly to the important class of marine polyps known to zoologists as *Anthozoa*, to which also belong their cousins, the sea-anemones. But, while each anemone is a separate, free-living individual, with the ability in many cases of crawling about at will, the reef-building corals live together in crowded colonies from which each polyp has neither the inclination nor the ability to stir a fraction of an inch, once it has established itself among its fellows during the early stages of its life.

Coral colonies display a bewildering variety of strange and beautiful forms. They may throw out a multitude of branches, so as to resemble the antlers of stags or the fantastic tree-ferns of a primeval coal forest. They may grow like rounded sponges; or like crater-pitted lumps of stone; or in serried rows of tubes, like the pipes of a fairy organ; or in the form of flowers, feathers, crumpled leaves, or softly crushed handfuls of tarlatan, like the dainty dress of a ballet-dancer reproduced on a tiny scale. We must remember that each of these forms is not an individual coral polyp, but a colony holding many of them or their skeleton remains, all intimately bound together into a whole.

About the Tiny Coral Animals

To illustrate the general structure of a coral animal, let us take a simple, individual madrepore polyp, one of those which are most in evidence on a coral reef. The hard mineral skeleton of this little creature forms a shallow cup, securely attached to the coral or rock beneath and firmly cemented to its neighbours. From the centre of this cup to its rim radiate a number of thin plates or *septa*, dividing the interior into numerous narrow cavities which in life are filled by the soft, fleshy partitions of the polyp's body. This living tissue covers the outside of the cup as well; and forming a fringe round its summit are many sensitive, waving tentacles which surround the simple orifice comprising the mouth. Although the numerous remaining species of coral-building polyps show every possible diversity of form, they can for all practical purposes be regarded as having an individual structure broadly similar to that of the species we have described. But it should be remembered that it is in the very diversity of the coralline forms and their wide range of vivid coloration that a great part of the beauty of a coral reef resides.

How the Coral Reef is Formed

Even in the largest of the separate coral colonies that go to make up a reef, all the living polyps composing it are intimately linked with one another by the joining of their soft tissues, so that a single polyp, though quite individual and complete in itself, yet forms but a small part of a large mass of living animal substance; and when it appeases its own appetite by sucking minute organisms from the sea-water into its voracious mouth, it is at the same time contributing to the well-being of its fellows.

Before we treat of the mighty submarine walls built by these tiny polyps, we must say something of the methods by which they increase and multiply. Many corals form their colonies by simple budding. A lumpy protuberance grows out from the side of the parent, which, gradually acquiring a mouth and tentacles of its own, becomes in time a complete and individual polyp, secreting its own skeleton to add to the masonry of the communal barricade upon its decease. When fully developed, this latest polyp proceeds in turn to put forth buds, and thus the colony rapidly increases, producing chiefly those corals that have the shape of branching trees or antlers.

There are other coral polyps, that propagate by "fission." The oval mouth of the polyp becomes constricted in the middle; a groove is formed, dividing the mouth into two equal

Courtesy of the Australian National Travel Association

A fairyland of fantastic shapes and brilliant colour The camera invades the lovely pools of the Great Barrier Reef and discovers (*top*) sea-urchins, starfish and bêche-de-mer among the coral

parts, and this groove gradually deepens until the whole body of the creature has been cleft down the centre. Thus two polyps have grown out of one, and though united, they are yet individual and distinct, and each has its own stony skeleton. It is by incessant division of this kind that the curious "brain-coral" is produced, in which the coral skeletons extend in a complex, maze-like formation over the entire surface of the colony, so that eventually the latter bears a remarkable resemblance to the convolutions of the human brain.

The Great Barrier Reef

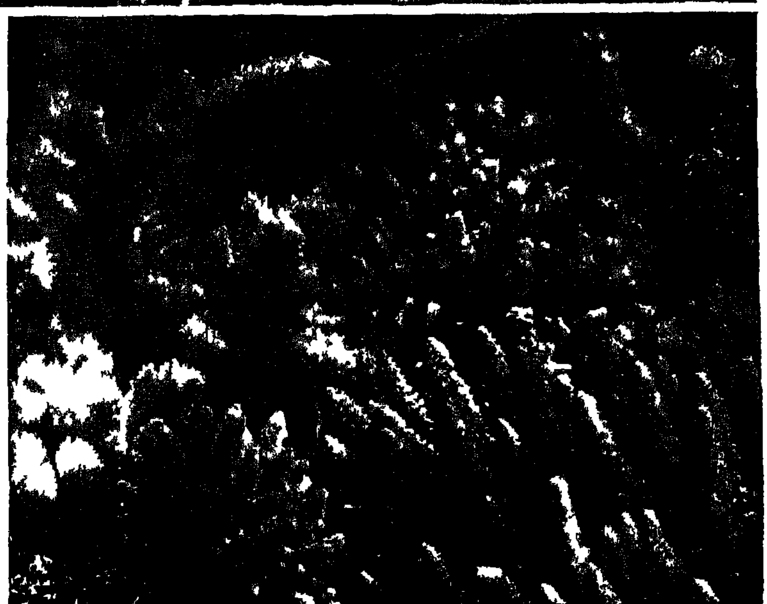
Let us turn now to the more impressive handiwork of these tiny, jelly-like polyps, and try to realize the truly grand scale of their achievements, which entitle them to rank as the greatest active builders of material things. For more than 1,200 miles along the north-eastern coast of Queensland stretches the Great Barrier Reef, the largest of all coral formations, with an area of roughly 100,000 square miles, composed almost entirely of the skeletons of departed polyps and their living descendants. Between the reef and the Australian mainland is a lagoon-like channel, varying between 20 miles and 70 miles in width, and with a depth of water in places of 400 feet, forming an admirable roadstead for the largest vessels where they are sheltered by the reef, as by a vast breakwater, from the long rollers of the Pacific. At intervals there are several deep, natural passages traversing the great wall of coral, through which ships may enter in safety.

It is difficult to determine the age of this great reef, but certainly it is many, many centuries since the first polyps clung to the submerged rocks and began the laborious initial steps in their great undertaking. The accumulated skeletons of their descendants must now weigh millions of tons.

It is not only by reason of its size and its origin that the Great Barrier Reef is a thing of wonder. The gorgeous colours of the coral rocks, extending as far as the eye can see, make an unforgettable picture. They might almost be taken for a gigantic garden stocked with exquisitely tinted flowers—violet, purple, crimson, orange, and brilliant emerald green. On approaching close to

Photo: Queensland Railway Commissioner

On the Great Barrier Reef, Australia. At low tide, the coral, in all its varied beauty, is exposed to view



Photos Noel Monkman and Queensland Railway Commissioner

The Barrier Reef teems with wonderful marine life. Here are gaily-coloured coral fish (*Tetradrachnum aruanum*) in the clear depths of a coral pool; while above, a sea star (*Blue linckia*) and a clam are seen on the edge of the reef at Heron Island

the reef the manifold different shapes of the coral colonies spring to the eye—many-branched and slender, like the trees of an enchanted forest, or winding backwards and forwards in an endless, complicated pattern; or inconceivably thin and fragile, or again outrageously fantastic and grotesque. Very prominent are the numerous colonies of star-corals, some of which assume the form of large, smooth, round boulders that look strangely like gigantic human skulls that have been left to bleach beneath the fierce sun. Another curious formation is that of the so-called organ-pipe corals, in which each member of the colony constructs a limy tube. All these separate tubes are connected firmly together by horizontal platforms, so that the colony strikingly resembles the flue-work of an organ. The pipes are

coloured a deep red, and the living polyps of this species are a vivid lilac or purple.

Then there are the brilliant porites, which play a leading part in building up the reefs, often sending up great branches of coral more than 20 feet in length from the clear depths of the sea, which act as piers and columns to the huge fabric, and carry other massive colonies on their summits, like brightly coloured birds' nests. Porites are found in great abundance on all tropical reefs. On the Great Barrier Reef they are tinted lilac, rich brown, deep yellow or a dainty pink; while on the reefs of the West Indies they are commonly a brilliant blue or delicate green. In part, the brilliant coloration of corals may be due to pigment cells in the tissues of the animals: but in many instances it is believed to owe its origin to the agency of minute parasitic sea algæ with which the polyps are infested.

As though the limit of extravagant coloration had not been reached in the coral colonies themselves, the Great Barrier Reef—and, indeed, practically every coral reef—has a host of other brilliant inhabitants, such as the lovely flower-like anemones (which we have described elsewhere), and many gaudily arrayed fishes, which make their homes among the coral-fringed pools, being careful to select as neighbours those polyps whose colours harmonize most fully with their own, whereby they become more or less inconspicuous to their numerous foes.

Coral formations are not distributed indiscriminately throughout the globe, but are found only in limited regions which have proved suitable for supporting the life of the reef-building polyps. Among the essential factors, one of the most important is the temperature of the ocean, which must not drop below 68° Farenheit at any time of the year. Thus, there are many waters even within the tropics in which reef corals will not flourish, owing to the proximity of cool currents. Another necessary condition is a favourable depth of water, which even for the deepest-living reef coral should not exceed 120 feet. Again, the sea must be rich in minute organic life, so as to provide the polyps with abundant food; and it should not be contaminated with mud or silt, or diluted with fresh water; from this it can be seen that coral formations wi l not be found in the seas bordering the mouths or estuaries of large rivers.

These essential requirements narrow down considerably the localities in which coral reefs and islands may be expected. None are found on the western coasts of Africa and America, and in the Atlantic as a whole they are uncommon. The Pacific, within certain latitudes, is particularly rich in coral formations; they are plentiful in the waters off the eastern coast of Australia, including among their number the Great Barrier Reef itself. The Solomon Islands, the Ellice Islands and New Caledonia are only a few of the many islands in this region that are of coralline structure. It is interesting to note, however, that though the rocky submarine shelf on which are built the Great Barrier Reef and all the neighbouring atolls which have given this region its name of the Coral Sea extends as far as New Guinea, the fresh, muddy waters of the Fly and other rivers prohibit the formation of coral along the southern shore line of Papua, and this region is devoid of reefs in consequence. Coral formations in the Indian Ocean include the Laccadive and Maldive Islands, the Chagos Archipelago, the Cocos-Keeling Islands, the Seychelles, Bourbon and numerous reefs fringing Madagascar and Mauritius. In the West Indies and off the coasts of Florida and Brazil there are numerous reefs, while the Bermudas enjoy the distinction of comprising the coral formation most distant from the Equator.

An Engrossing Subject

The numerous points of interest presented by coral reefs and islands have engrossed the attention of many naturalists. The earlier of these believed that the coral structures were built up solidly from the bed of the ocean; but when it was discovered that the reef-building polyps cannot flourish in water of a greater depth than about 120 feet, the conclusion was reached that all coral formations in deep water must rest upon submerged banks or volcanic cones reaching to within 120 feet of the surface, though it seemed difficult to account for the occurrence of so many of these submerged platforms all of the correct height, scattered so conveniently throughout the tropical seas of the world.

During the celebrated voyage of the *Beagle*, Charles Darwin had plentiful opportunities of studying coral formations; and, becoming dissatisfied with existing theories, he devoted much thought and study to the problem, eventually publishing a monograph on the subject ("The Structure and Distribution of Coral Reefs"), in which his famous Subsidence Theory was given to the world. Darwin's views met with widespread criticism, but eventually his theory was accepted

Courtesy of the Australian National Travel Association

Captured edible Green Turtles (*Chelone midas*) placed in a "safe" position on the sand

Photo Otho Webb Embury Barrier Reef Expeditions

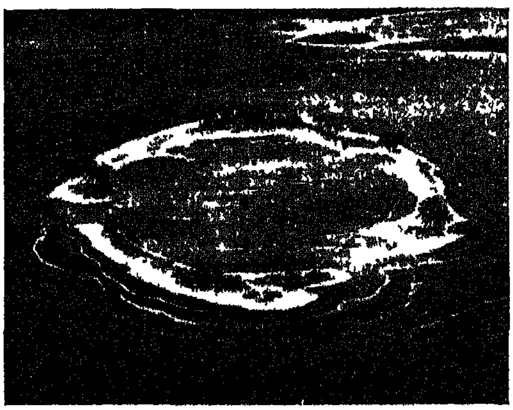
Turtles are found in large numbers in the tropical waters around the Barrier Reef

Young Loggerhead Turtles (*Chelone Imbricata*) about to leave their nest—a hole in the beach about a foot deep—for the sea

by the main body of scientists as the most feasible explanation of the growth of coral structures; and though challenged from time to time by other eminent authorities, it is, perhaps, on the whole the most consistently reasonable of all the suggestions that have been put forward.

Darwin recognized three principal forms of coral reef—fringing reefs, barrier reefs, and atolls. Fringing reefs are coral formations, usually of no great size, which surround islands or skirt the shores of continents. They are perhaps the commonest types of coral structures in all tropical seas, and are distinguished by the absence of a deep channel separating them from the land.

Barrier reefs occur usually at a much greater distance from land than fringing reefs, and they are separated from shore by a deep channel. Further, their seaward margin generally gives indications of rising abruptly from a great depth of water, which is not the case with fringing reefs. All these traits are exemplified in the Great Barrier Reef of Australia. This is more properly described as a "linear" barrier reef. There is also the "encircling" type of barrier reef, which surrounds an island, or land-mass, but is separated from it by a deep lagoon.



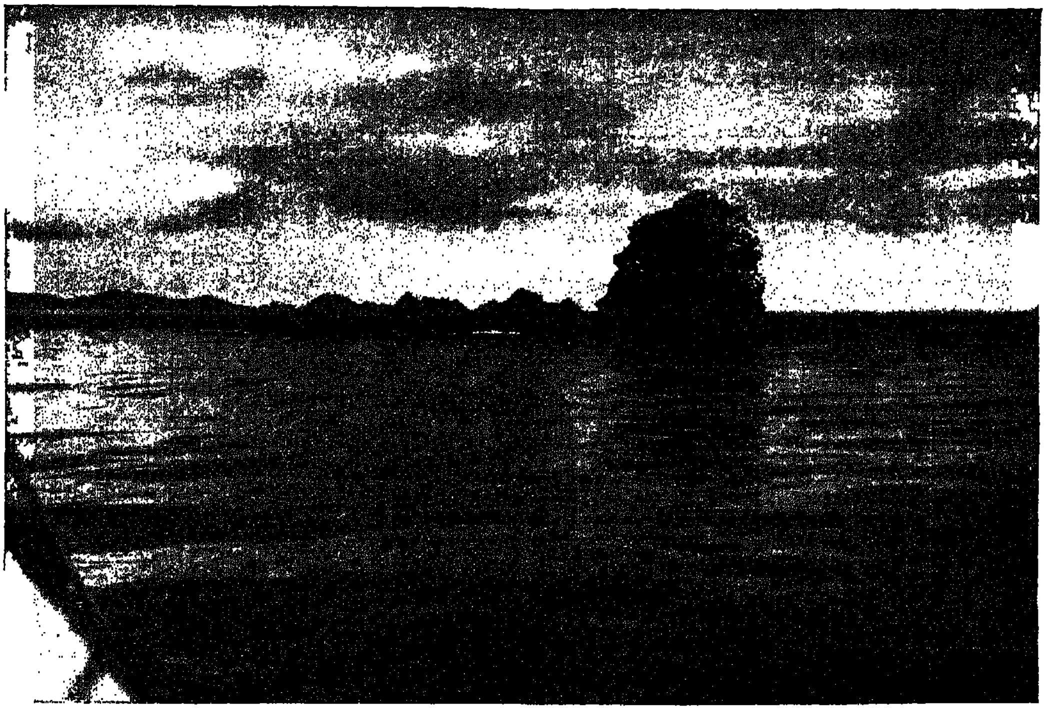
A coral atoll usually takes the form of a horseshoe, enclosing a lagoon

Atolls, which mainly comprise the familiar "coral islands," are coral reefs in the form of a ring or a horseshoe. The latter is the more usual shape, with the opening turned towards the leeward; on this side the growth of the coral has been less rapid and complete, for the polyps, under-nourished and choked perhaps with sediment, have lacked the advantages of the constantly renewed water which has stimulated their more fortunate relatives to windward. An atoll is in all respects similar to an "encircling" barrier reef, except for the fact that the lagoon which it encircles does not surround an island.

The upper layer of any coral structure may be exposed at low tide, and the reef may be artificially heightened by sand, driftwood, dust and fragments of dead coral broken off by the waves, so that in time it stands permanently above the water. Drifting trees, bushes and fruits—such as pineapples and coconuts—and seeds contained in the floating carcasses of dead birds, or in the droppings of living ones, provide the beginnings of vegetable life, and the vegetation increases and enriches the soil in its decay; so that in time there appears a substantial land-mass, thickly teeming with life, and founded upon the skeleton remains of millions of industrious polyps. Such has been the wonderful, if humble, history of many of our most prosperous and fertile islands, with their towns, houses, shops and roads, their manufactures, harbour-works and local government!

These three main forms of coral structure, maintained Darwin, were but successive stages in one continuous process of growth, so that all atolls had at different periods of their history been fringing reefs and then barrier reefs, before assuming their most recent form; and, similarly, all reefs are but immature atolls. The manner of their growth, according to Darwin, is as follows: 'It is a familiar fact that many portions of the earth's crust are gradually sinking or settling, while other regions are just as gradually being upraised. Suppose a number of polyp colonies starts to build on the submerged shores of an island which is slowly subsiding into the sea, then the upward growth of the coral will tend to neutralize the settling of the land, so that the reef will appear to be stationary, while actually its lower strata are being thrust deeper and deeper into the sea. The coral at this comparatively early stage forms a *fringing reef* round the island.

"The seaward border of a coral reef is always the most active and vigorous, since it has the benefit of an unrestricted food supply from the free circulation of the water, and by heavy waves is scoured clean of the sand and dead coral which otherwise would impede its growth. Therefore the outer fringe of coral continues to grow upward, while the stunted inner coral, unable to keep pace with the subsidence, sinks lower and lower and is eventually covered by a channel of deep water, which separates the vigorous part of the reef from the gradually diminish-



Courtesy of the Australian National Travel Association

Mondiale

A coral island in the Bahamas

Top: "Pinchgut," a coral atoll in the Cumberland Group, Whitsunday Passage, Australia

ing land. The fringing reef has now become a *barrier reef*, which, if it be of the encircling type, encloses a lagoon that has a small peak of land in its centre.

"Meanwhile the subsidence continues until the last fragment of this land disappears beneath the waters of the lagoon; the reef has now taken the form of an *atoll*, roughly circular in shape, which, as we have seen,

Photo Otho Webb-Embury Barrier Reef Expedition

Luxuriant vegetation is characteristic of the Barrier Reef Islands—Convolvulus in a Pisonia forest on Nor'-West Island

becomes a nucleus for sediment and rubbish of all kinds, and after long ages is transformed into a more or less habitable island."

Such was Darwin's theory explaining the building of coral structures. It gained immediate acceptance among many scientific men, and is perhaps the theory most generally held to-day. But several scientists opposed it, chief among whom were Louis Agassiz and Sir John Murray, the distinguished naturalist of the *Challenger* expedition. Darwin had objected to the older theories of coral formation on the ground that it was inconceivable for there to be so many submerged peaks massed in the tropical seas at just the right distance below the surface for coral polyps to start their operations, without a great many peaks appearing also above the surface, far in excess of those that actually project; but Murray contended that submerged banks and mountain peaks, lying originally at a depth at which no coral polyps could flourish, might in time be raised high enough to come within the range of their activities by the incessant rain of skeletons of minute sea organisms from the waters above, and by the depositing of other debris.

Having become firmly established, argued Sir John Murray and his supporters, the coral colonies will continue to grow upwards until they break the surface of the water, the reef taking the form of a typical atoll ring, if it had been founded around the conical peak of a submerged mountain; or of a linear reef—such as the Great Barrier Reef—if built originally upon a submerged ridge or bank. The polyps on the outer fringe of the reef will, as we have seen already, grow with the greater vigour, so that the periphery will be raised higher than the centre. In the centre, moreover, not only will the coral be stunted and feeble, but the dead portions of the rock will be eaten away by the chemical action of the sea-water and washed away by the tide, so that eventually the reef will entirely surround a lagoon.

This reasonable theory disregards the subsidence of the land altogether, and thus it serves to explain the occurrence of coral reefs and islands in regions where the earth's crust was known to be actually rising, instead of settling, as is the case in the Pelew Islands, in the North Pacific. The researches of other workers have further made it plain that for several cogent reasons many of the world's coral formations—including the Florida Reefs, the Fiji Islands, some of the West Indian Islands and perhaps also the Great Barrier

Photo Otto Webb Embury Barrier Reef Expeditions

A magnificent bank of *Tournefortea argentea* in flower on a coral island in the Capricorn Group

Courtesy of the Australian National Travel Association

Grove of tropical palm trees on Lindeman Island

Reef—do not seem to have been formed in areas undergoing subsidence.

In 1896 a scientific expedition set out for the Ellice Islands, in the Pacific, for the purpose of making borings through the coral rock in an endeavour to clear up the problem of coral formation by an inspection of the various materials encountered. Borings made through the coral reached an extreme depth of 1,114 feet. The core of rock extracted by the drill was found to consist entirely of limestone, comprising the remains of corals and of lime-secreting algæ and other organisms; but even at this great depth neither the subsided land nucleus of Darwin nor the submerged mountain peak of Sir John Murray was reached by the drill, leaving the evidence inconclusive. However, a boring made through the water of a lagoon into the rock beneath revealed the existence at a depth of over 270 feet of the remains of various corals that flourish only in seas of a much shallower depth than this. Such evidence was taken as conclusive proof that this island at least had been formed by subsidence; and that, during the gradual settling, the floor of the lagoon had been maintained at a fairly constant level by successive generations of polyps.

Neither of these two main theories of coral growth serves by itself to explain the formation of all the reefs and atolls that are met with; and, indeed, it seems likely that there is no single true explanation, but that in different circumstances different causes have operated in the erection of these massive natural walls and islands.

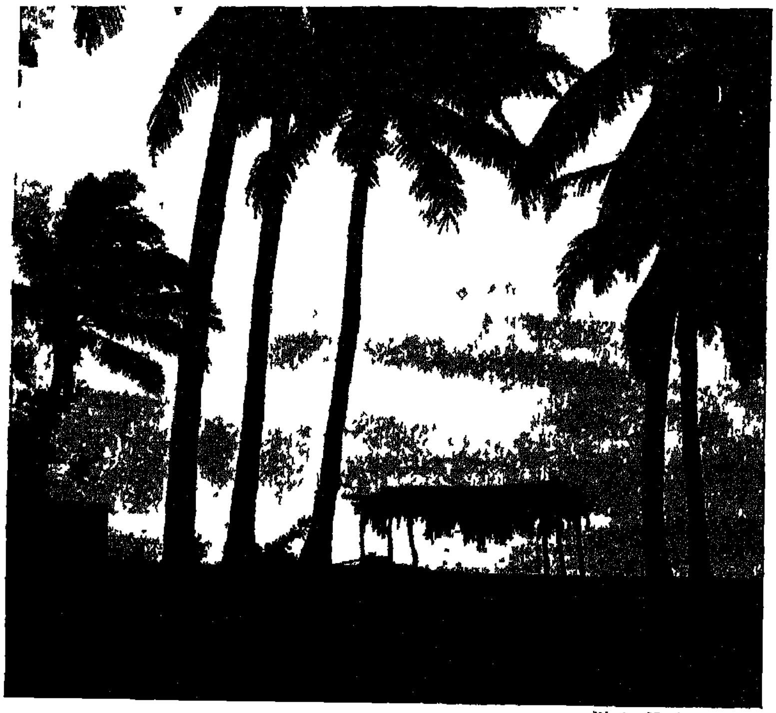


Photo Noel Monkman

Dusk falling over the coral islands of the Barrier Reef can be one of the loveliest sights in the world—Green Island, near Cairns, Queensland

So far we have made no mention of that kind of coral with which everybody is most familiar—the red, or precious, coral. This is found principally in the Mediterranean, and though of no use in land-building, it has since time immemorial been a favourite article of personal adornment and has been the object of a large and widespread trade. The Romans had implicit faith in the medicinal powers of coral and in its efficiency for averting the "evil eye"; and the modern Italians still wear fragments of coral for this latter purpose. In the East, from very ancient days, red coral has been fashioned into charms and jewellery and employed for every kind of ornament; and very high prices are obtained for the finest qualities. In Kashmir, records Marco Polo, writing at the end of the 13th century, coral imported from Europe was sold at a higher price than in any other part of the world; while in Tibet it was used as money and for the adornment of idols.

In the Middle Ages, and for long after, the right of coral-fishing along the North African coast was a jealously guarded monopoly, Italy, Spain, France and—during the Napoleonic Wars — England successively enjoying this privilege; in modern times France has once again assumed the monoply, and the fishing of the valuable Algerian reefs by foreigners is only permissible under a duty. A space of ten years is deemed long enough

for the coral polyps to replenish the reefs, and so the latter are divided into ten regions, of which only one is fished in a year, the others being strictly preserved. When the coral has been torn from the sea-bed by means of a special dredge it is cleaned, graded, sold and despatched to the manufactories, which are centred principally in Naples, Leghorn, Genoa and Rome, a few being located also in the native bazaars of Egypt and North Africa.

Coral of superfine quality, tinted an exquisite rosy pink, has been known to fetch the extraordinarily high price of £120 an ounce, while a similar quantity of the small scraps and fragments which are left over as waste from the manufacture may be obtained for a few shillings.

CHAPTER VIII

BOATS THAT SKIM AND BOATS THAT SWIM

TO those who are not conversant with boating terms the word "hydroplane" may suggest a flying-boat or a seaplane rather than a motor-boat. The term is certainly confusing, because the earliest flying-boats originated from the hydro-aeroplane, an entirely different invention from the hydroplane, which latter the inventors hardly intended should take wings to itself and fly.

Points about the Hydroplane

The hydroplane, however, is not an ordinary boat, for entirely different principles are involved both in its construction and in its manner of riding the water. In other types of watercraft the hull is buoyed up by pressure of the water displaced: whether the boat be floating stationary or be in motion the weight of the boat displaces an equal weight of water, and as the boat travels along, the water in front of it is merely pushed aside, while the amount of water displaced remains practically the same. The hydroplane, in contrast, is so built that when in motion it rides on the surface of the water and is kept afloat, not by displacement, but by the thrusting downwards of a certain mass of water as it forges along—in much the same way that an aeroplane is supported in the air by its wings.

The hydroplane is very lightly constructed and has an almost flat bottom which is shaped in such a way that when the craft is travelling at a high speed the pressure of the water on the bottom raises the boat to the surface. The flat stones we sometimes skim over the surface of a pond are acted on by similar forces, and if it were possible to project them with sufficient velocity, there is no reason why they should not go on skimming.

Hydroplanes are provided with what are termed "steps": the bottom of the boat, instead of being formed in one continuous longitudinal plane, is built in two or more inclined planes, each separated by a step from the next. When such a boat is turned upside down, its bottom is seen to form two or three steps rising from stern to bows. The reason for this is that steps assist in overcoming the frictional resistance of water. If the bottom of the boat were formed in one plane the entire surface would be subject to the resistance of the water; by making the after part of the hull in a higher longitudinal plane, however, this resistance is lessened. When the boat is driven over the water at a high speed, air is drawn between the surface of the water and the rear part of the bottom of the boat and remains there, supporting the after part of the hull and keeping it out of actual contact with the water. The craft therefore skims along with only the forward part of the hull immersed, and that only to a shallow draught. Thus frictional resistance is lessened and higher speeds are made possible.

Boats of this description were built nearly fifty years ago, but not until the internal combustion engine was invented did they get beyond the experimental stage. Nowadays all high-speed racing craft are of the hydroplane type and it is to racing that the hydroplane owes most of its popularity. The first important racing event in this country was inaugurated by Sir Alfred Harmsworth (later Lord Northcliffe) in 1903. It was named the British International Trophy and was won by Mr. S. F. Edge in *Napier I.*

The British International Trophy

In the following year the same pilot was successful in *Napier Minor*, which averaged

23½ miles per hour. In 1907 the trophy went to America, where it remained until 1912, when it again returned to this country. Mr. Mackay Edgar was the pilot on this latter occasion, and he accomplished a speed of over 40 knots in a forty-foot hydroplane, named *Maple Leaf IV*, which was fitted with a 760 horse-power Austin engine. In the following year the same pilot and boat exceeded 50 knots—that is, about 57½ land miles per hour. During the Great War no racing took place, but in 1920 Mr. Gar Wood won the trophy by attaining a speed of 56 knots in *Miss America*, a twenty-six-foot boat with an 800 horse-power engine. Since then, in spite of various British attempts to win it back, the trophy has remained in America.

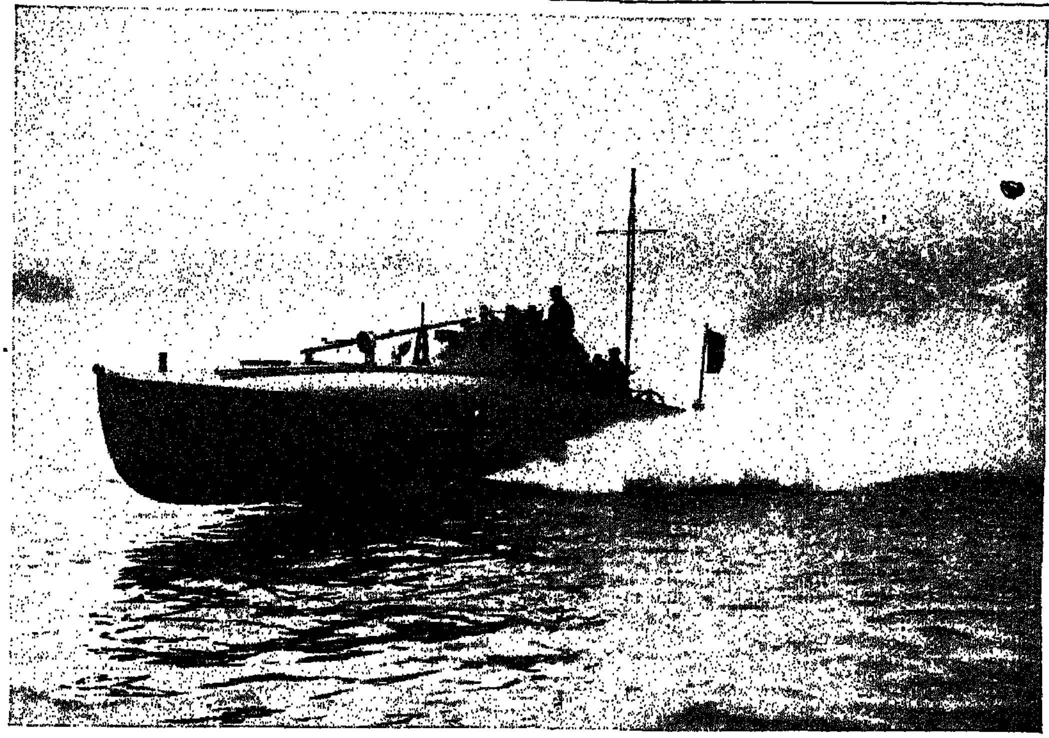
Britain and the Speed Record

Although Britain has failed to regain the International Trophy, it holds the world's speed record for racing motor-boats. In 1928 Major Henry Segrave (later Sir Henry Segrave) went to America with *Miss England*, a single-step hydroplane having a 930 horse-power engine, to compete against Gar Wood's *Miss America VII*. The American boat had engines capable of developing 2,300 horse-power. To everyone's surprise—for his attempt was very hastily planned—Segrave won at a speed of 90 miles per hour. His success was partly due to the fact that Gar Wood had underestimated his opponent's skill and took risks which resulted in the failure of his own steering gear.

Segrave's Death after attaining 101 miles per hour

The victory stimulated British interest in motor-boat racing and steps were immediately taken to capture the world's speed record. In 1930 the *Miss England II* was completed and fitted with a pair of Rolls-Royce engines capable of developing 3,800 horse-power. Segrave took the hydroplane to Lake Windermere, in Cumberland; and on June 13, with his two mechanics, Willcocks and Halliwell, made his attempt on the record. The first run over the measured mile was made at a speed of 96·41 miles per hour, and the second at 101·11 miles per hour—giving a mean speed of 98·76 miles

High-speed motor-boat racing and attempts on the speed record may be thrilling to watch but they are fraught with great danger to those in control of the heavily-powered boats. Sir Henry Segrave, one of the greatest pilots of racing craft of all time, lost his life at the helm; but Mr. Kaye Don and, later, Mr. Scott-Paine (seen above in *Miss Britain III*) have come forward to uphold British prestige in this field of sport



Tearing through the water at a speed of over 40 knots—a 900 h.p. Thornycroft motor torpedo-boat on test. One of a fleet built for the Siamese Government, this craft carries torpedoes, machine-guns, depth charges and apparatus for creating a smoke screen

per hour, which set up a new record. Unhappily, during a third attempt to raise the record still higher, the boat suddenly capsized and sank, Halliwell and Segrave both losing their lives.

It is believed that the boat struck the submerged branch of a tree, which tore a hole in its bottom. The new mean speed was accepted as a world's record, but did not stand for long. In March of the following year Gar Wood, in *Miss America IX*, recaptured the record with a speed of 102·25 miles per hour. *Miss England II* was repaired and strengthened, and on April 3, 1931, Kaye Don, now the British challenger, regained the record with a speed of 103·5 miles per hour; this run was made on the Paraña River in Argentina. In July of that same year, on Lake Garda, Italy, Kaye Don raised the record still higher with a speed of 110·28 miles per hour. The present record is held by Gar Wood, who attained 128·98 miles an hour on Lake Michigan in 1936—a magnificent performance.

It must not be concluded that the hydroplane's sole utility lies in racing, though in the experimental stages that might have been the case. Before this phase had passed, however, the high-speed motor-boat entered into an entirely different field of use. Long before 1914 it had occurred to certain naval experts that the hydroplane might be made use of in warfare. It was thought that if two or three boats of this description were carried on a larger war vessel they could, when opportunity arose, be released to dash in and at close range launch torpedoes at enemy ships. Their great speed, their sha low draught, and the ease with which they could be manœuvred would make them difficult targets for enemy guns, and altogether they would be a useful auxiliary to the destroyer fleet.

The First Steam-driven Torpedo-boats

Little progress with this type of craft was possible, however, until the internal combustion engine had been perfected. Sir John Thornycroft's firm was the first really to exploit the possibilities of the hydroplane torpedo-boat, and they persevered with their experiments right up to the outbreak of war in August, 1914. In the first year of the war three naval officers, Lieutenants Anson, Bremner and Hampden, managed to convince the Admiralty that fast hydroplanes

could be made practicable war vessels; and in 1915, twelve forty-feet single-step hydroplanes, carrying one torpedo each, and fitted with 250 horse-power motors capable of giving a speed of 30 knots, were designed and built. They became known as coastal motor-boats and proved their usefulness so soon that faster and larger boats of the same description were immediately put in hand.

Coastal Motor-boats for Torpedoes

The new type of coastal motor-boat carried two eighteen-inch torpedoes, was fifty-three feet long, and had a pair of 375 horse-power motors that gave a speed of 40 knots. Later, still larger boats, seventy feet long, were built.

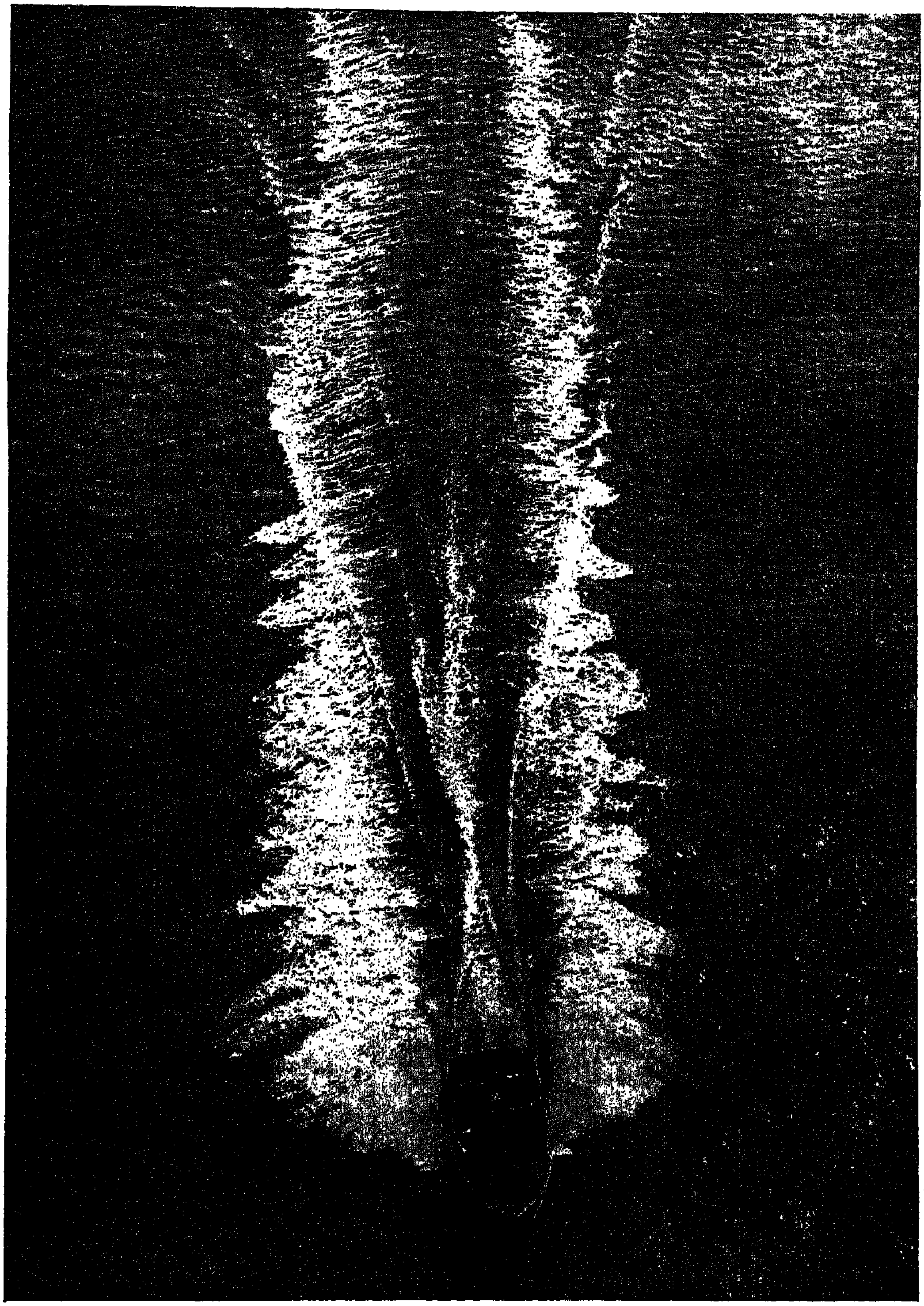
The greatest problem in constructing the first fleet of coastal motor-boats was that of weight, since they might not exceed four and a half tons if they were to be hoisted on board a mother vessel. Taking into account the weight of the engine and that of the torpedo, it will be realized that the hull of the hydroplane would need to be very lightly built, a fact that virtually prohibited the use of metal. A further problem was that of finding a safe and effective method of discharging the torpedo. Eventually this was overcome by carrying the torpedo in a slide and firing it tail first from the stern. In view of the fact that when the torpedo had been discharged it immediately shot forward in the path of the motor-boat, the latter had, of course, to execute a quick manœuvre to avoid being struck and blown up by its own death-dealing projectile. The larger type of coastal motor-boat was not designed to be hoisted on board another ship; nevertheless, in order that it should be able to attain maximum speeds, this craft was designed on the lightest possible lines.

The Motor Launch in Naval Operations

During the War, in addition to attacking vessels with their torpedoes, these boats served a number of other useful purposes, creating smoke screens for warships and guiding these vessels by laying flares at night. During the Zeebrugge raid on St. George's Day, 1918, they played an important part in screening our own vessels with smoke and in torpedoing enemy destroyers. After 1918, motor-boats took part in attacks on the Bolshevik fleet and succeeded in making their way into Kronstadt harbour, where several vessels of the Russian naval fleet were torpedoed. Since 1918 coastal motor-boats, developed on special lines, have become an important arm of all war services in nearly every country possessed of a seaboard. In Britain the Navy, the Army and the Royal Air Force all have their own fleets of motor-boats, and while construction may differ slightly in detail, the basic essentials are the same. Italy, in particular, has developed this type of naval vessel extensively for use in the Adriatic and the Mediterranean.

Another type of motor-boat which has been developed for war purposes is the motor launch. In this case the boats were used to relieve the destroyers and other larger vessels from patrol duties, so that the latter might be freed for more important work. The launches were a great deal bigger than the coastal motor-boats and were "displacement" vessels. Instead of carrying a crew of two or three men—which was all the coastal motor-boats could accommodate—they carried two officers and eight men; were seventy-five feet to eighty feet in length; and were fitted with a pair of 220 horse-power petrol engines giving a maximum speed of 20 miles per hour. While their duties were not so spectacular, perhaps, as those of the coastal motor-boats, they nevertheless performed many heroic feats, notably at Zeebrugge and Ostend. As everyone who has read of the raid at Zeebrugge knows, one of the aims was to block the canal by ships that were run into its mouth and deliberately sunk, so as to prevent the ingress and egress of German submarines. The crews of the blockships knew that there was a slender chance of coming out alive, and the danger to the attendant motor launches was little less, since upon these craft devolved the duty of picking up the men from the sunken vessels. In due course the official report on the raid was issued by the Admiralty, and the following extract shows clearly though briefly the part played by the motor launches:

"With the two officers and two petty officers Lieutenant Bonham-Carter launched a Carley raft and went down the canal until picked up by Motor Launch 282. This motor launch came out into the canal under the stern of the *Iphigenia*—the next blocking ship—under heavy fire. She was commanded by Lieutenant Percy J. Dean, R.N.V.R., whose conduct Lieutenant Bonham-Carter describes as simply magnificent. 'I have had the pleasure,' he says, 'of recommending this officer to their Lordships for promotion, and I consider his gallant conduct is well worthy of the Victoria Cross.'"



The motor-launch developed for use in the Royal Navy—one of the new speed dinghies travelling at over 20 knots during official trials at Cowes. These tiny vessels will be used for such purposes as communication between warships and the shore and between one ship and another

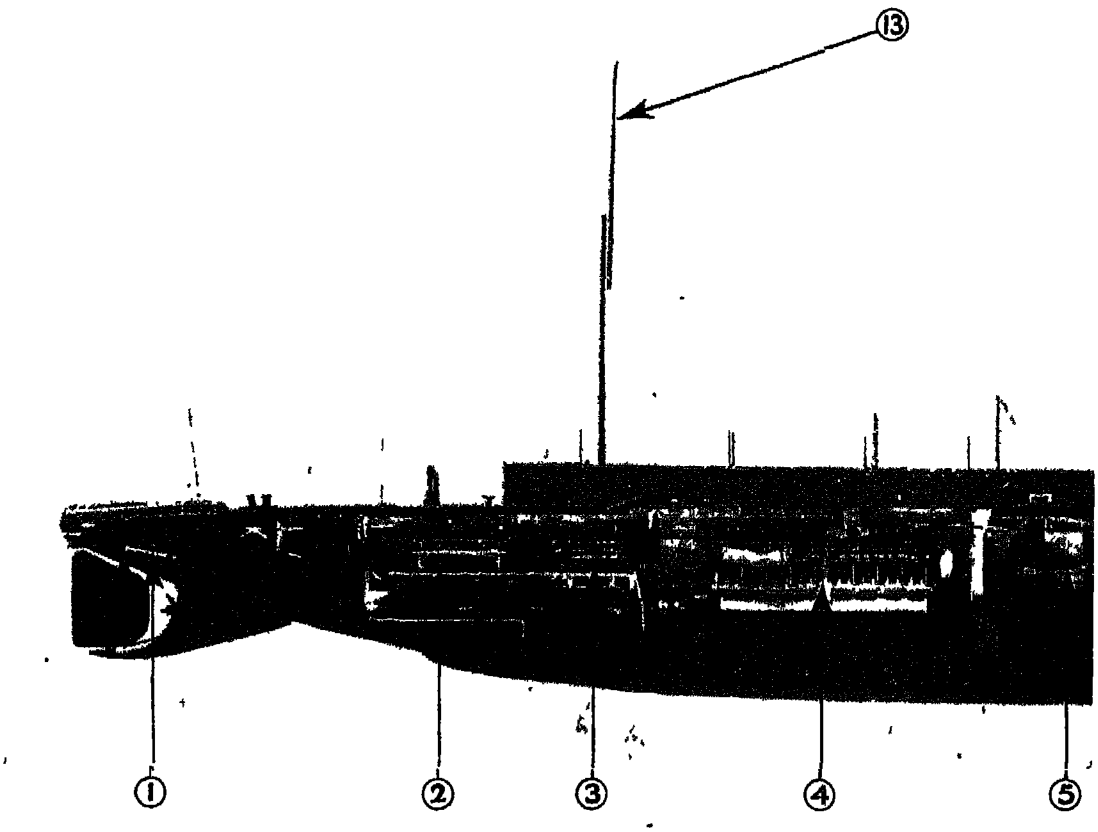
The report goes on to tell of the coolness and courage of the officers and men of the motor launches who rescued the crews of the other blockships when their work was completed

Outboard Motor Craft

There is to-day a large number of motor-boats which are solely pleasure craft, for motor-boating is becoming increasingly popular. Much of this popularity is due to the introduction of the portable outboard motor which, by means of a clamp, can be attached to or detached from the craft at will. In England, outboard racing began in 1923, and in those days 10 miles an hour was considered a good speed; but the outboard hydroplane quickly followed and superseded, so far as high-speed racing was concerned, ordinary outboard craft.

By 1928 outboard motor-boat and hydroplane racing was in full swing; and in 1929 a run from Dover to Calais and back was organized for these vessels. The contest turned out a failure, and it was very fortunate that no casualties resulted. On the morning of the race thirty-six boats set out, but visibility became very bad. Most of the competitors had no experience with such craft on the open sea, and soon discovered that outboard racing on rivers and sheltered waters was a very different proposition. A few competitors reached the French coast safely, but the majority had to be rescued by patrol boats; and some were even forced to spend the night on the water, with their frail craft tossing about helplessly until at last they were picked up cold and exhausted. Had a storm blown up or even a moderate gale, the result might have been disastrous; and in all probability a number of boats would have gone down.

The immediate effect of this race was to discourage the use of light outboard craft for sea racing, although the outboard hydroplane still retains its popularity for speed



Longitudinal section of the British submarine I

1. One stern torpedo tube. 2. Mess deck. 3. Motor room. 4. Diesel engine room. 5. Mess deck.
torpedoes. 12. Two bow torpedo tubes. 13. Telescopic wireless masts. 14. Twin periscopes. Though
remain the same and this illustration should be studied in

contests in sheltered waters. King Edward VIII, when Prince of Wales, took to the sport enthusiastically and bought and raced hydroplane craft. Another effect of the abortive Dover to Calais race was that it led to the introduction of the outboard dinghy which, so far as sea racing is concerned, has superseded the hydroplane. The outboard speed dinghy, complete with motor, can be bought for about half the price of a small car. An ordinary outboard dinghy, not designed for racing, costs even less and provides at small expense a great deal of pleasure for those content to travel more leisurely. Punts, too, can be fitted with outboard motors; indeed any light craft can at little cost be converted into a motor vessel.

Of all the modern mechanical inventions probably the submarine is the most marvellous; certainly it is the most complicated, for many of its technicalities are unknown even to the average engineer. One of the earliest attempts at a submersible vessel was made with an ordinary boat the deck of which was completely covered and the hull enclosed in a casing of leather thoroughly smeared over with grease. The method of propulsion was with oars which were passed through holes, the latter being protected by diaphragms which prevented the water from getting into the hull. Air was admitted to the inside of the vessel through a hollow mast. In 1620 an inventor named Cornelius van Drebbel is said to have travelled under water from Westminster to Greenwich in a boat which he had constructed, the vessel being immersed only a few feet below the surface.

How the Early Submarine Worked

A big step forward in submarine invention was made in 1747 by a man named Symons, for he realized that a boat could be made to sink or rise at will by varying its displacement and thereby its buoyancy; this he did by allowing water to enter air chambers

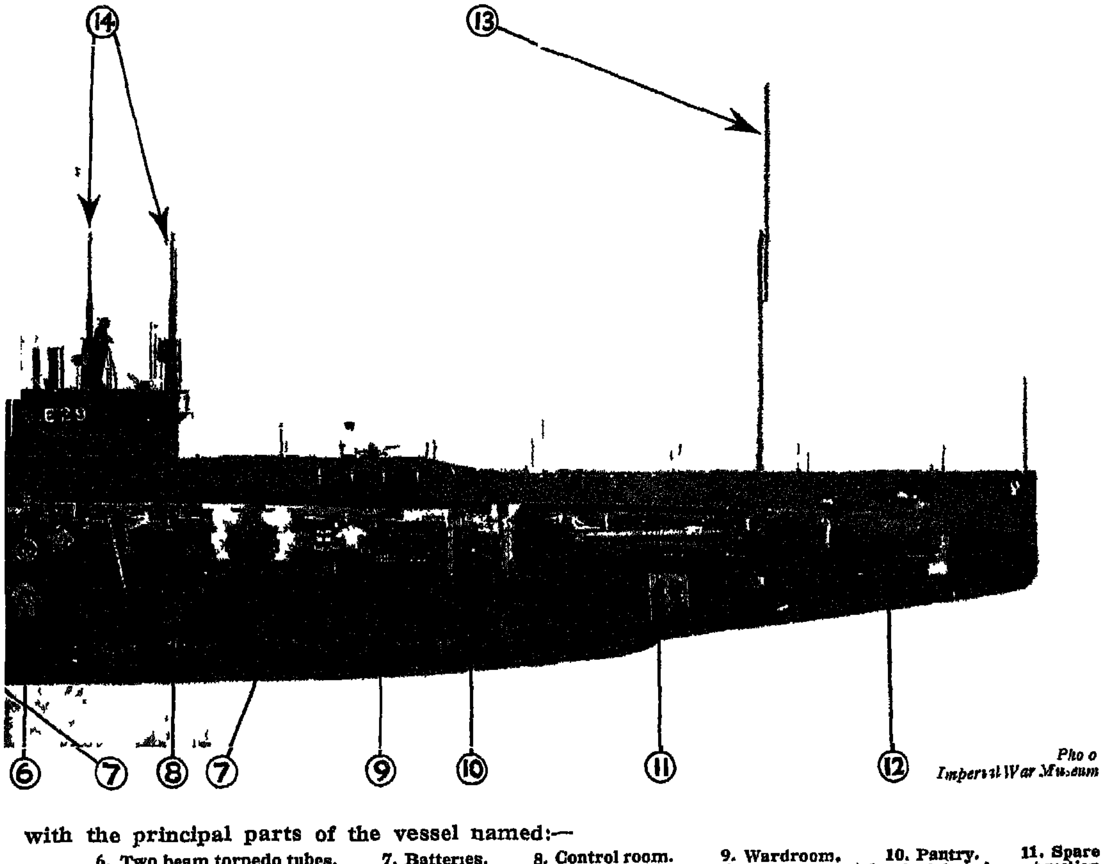


Photo Imperial War Museum

with the principal parts of the vessel named:—

6. Two beam torpedo tubes. 7. Batteries. 8. Control room. 9. Wardroom. 10. Pantry. 11. Spare this type has now been superseded by submarines *of more recent design, the essential principles* of construction conjunction with the interior photographs on succeeding pages

built into the vessel and by pumping it out again when occasion demanded. It is by the use of this same principle that modern submarines are able to sink below the surface of the sea and rise again at will. The first real submarine was built by David Bushnell, an American, in 1771. Only one man could sit in it, and it was propelled by means of a hand gear inside the boat operating a propeller at the stern. An ordinary rudder was used for steering and a tank at the bottom of the vessel contained ballast water. Bushnell's submarine, called the *Turtle*, was built for use against war vessels, and during the American War of Independence an attempt was made to blow up the British warship *Eagle*, then lying in the Hudson. Bushnell never succeeded in attaining his object, because of difficulties in exactly locating enemy vessels and in attaching to their hull the explosive mine his vessel carried.

Robert Fulton, famous for his steamboat *Clermont*, was the next submarine inventor, and while his principles were much the same as Bushnell's his boat was entirely different in shape. Bushnell's boat was more like a buoy in appearance, while Fulton's was cigar-shaped. Napoleon I aided Fulton with money, but the French government were not enamoured of the submarine and the venture was abandoned.

Gustave Zédé's Submarines

In the latter half of the nineteenth century, inventors again began to tackle the problem of building an effective submarine. Garrett and Nordenfeldt constructed a cigar-shaped craft, which was driven on the surface by a steam plant at the rate of 9 knots. When it was desired to submerge, the furnace and chimney were closed, and under the water the vessel was driven at 4 knots by the energy obtained from steam still remaining in the boiler. In 1888 the Frenchman Gustave Zédé launched the *Gymnote*, a cigar-shaped vessel built of steel. It was fifty-nine and a half feet long and six feet deep, and displaced thirty tons of water. A 55 horse-power electric motor was driven by 564 accumulators and gave a speed of 7 knots under water. The boat had a conning tower and a periscope, and horizontal planes were employed to guide the submarine vertically up or down in the water.

Another French submarine, the *Gustave Zédé*, was launched in 1893, but in spite of great expectations proved rather a disappointment. It was 160 feet in length, and twelve and a half in beam, and its displacement was 370 tons. Two electric motors, of 360 horse-power each, were used for propulsion and the vessel carried three eighteen-inch Whitehead torpedoes. The chief weakness of the *Gustave Zédé* lay in the fact that her great length made her difficult to steer; and a secondary weakness was that she was so buoyant that the boat plunged from side to side and made life uncomfortable for her crew. As an experimental vessel, however, she proved extremely valuable; after having many improvements made to her, she succeeded in 1901 in passing unobserved through the French fleet, proving that had she been intent on destruction she might easily have sunk some of the ships.

Origin of the Modern Submarine

The original designs of the three inventors Robert H. Whitehead, John P. Holland and M. Laubeuf are those on which nearly all modern submarines are based, the two last-named inventors deriving inspiration from Whitehead's torpedo. We may distinguish three main types of submarine according to their fundamental design: the single-hull, the double-hull, and a type which is a combination of the two, having some parts of the vessel constructed with a double hull and other parts with a single wall. John P. Holland's invention was of the single-hull type and has been followed by the British, American, Japanese and Spanish navies. The Laubeuf type has a double hull, and submarines of the French, German and Austrian navies were modelled on it. The composite hull, designed by an Italian named Laurenti, is used by the Italian, Portuguese and Brazilian navies.

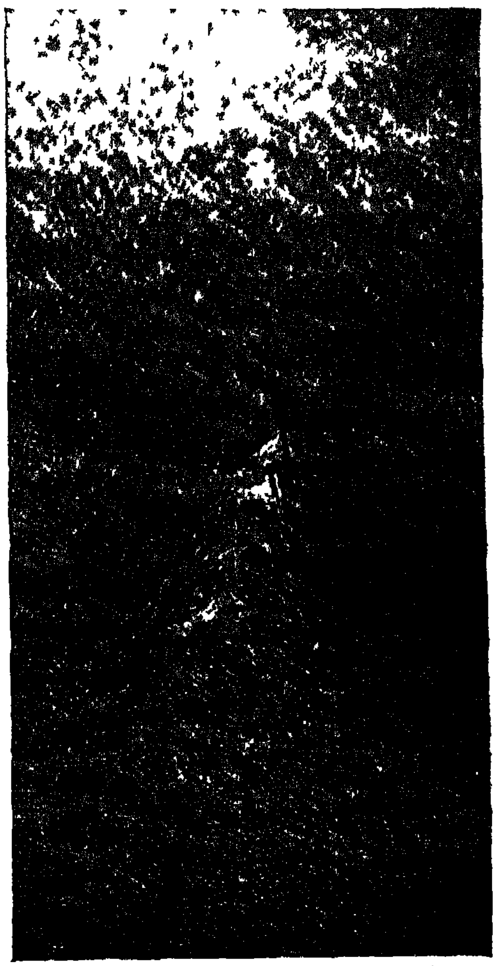
Most navies build two types of submarine, a smaller one for coastal defence and a larger for operation on the high sea. The small ones are generally of about 600 tons displacement (submerged), while the larger seldom displaces less than 1,000 tons.

Some idea of the importance of the submarine in modern navies can be gleaned from a brief review of the number of such craft possessed by the Great Powers. Of roughly 375 included in official returns for 1935, Great Britain had 51; France 82; the U.S.A. 84; Italy 64; and Japan 57. Germany had only 14 submarines, and Russia 23. British submarines of the "Thames" type, constructed in 1931–35, have a surface displacement of about 1,800 tons and a submerged tonnage of about 2,700. The nominal horse-power is 10,000 with a speed

of 22¼ knots on the surface. Submerged, the motive plant has an output of 2,500 horse-power and the speed is a mere ten knots. By contrast we may mention the "Swordfish" type, with a displacement of 670–960 tons, an output of 1,300–1,550 horse-power, and a speed of 10 to 13¾ knots.

The Submarine's Dual Power Plant

A submarine is a vessel which must be capable of travelling on the surface of the water like an ordinary ship—and nowadays they travel almost as fast—and must also be capable of total submergence and of navigation in this latter state. When the vessel is to be submerged, its buoyancy—that is its ability to float on the surface—is overcome for the time being by admitting water into specially constructed tanks, called ballast tanks. Those tanks must be of the required size, almost but not quite to destroy the buoyancy of the ship; if they admit too much water the vessel will sink like a stone. When the tanks are full the submarine is just on the point of sinking, and is said to be in "diving trim." It can, however, submerge only when the vessel is travelling along at about four knots; the diving rudders, or "hydroplanes" as they are generally called, cannot function until that speed has been reached. It has been said that the tanks must be full when the submarine is in diving trim, but this only refers to the main ballast tanks. There are auxiliary tanks which are used for trimming the vessel, and there is also the buoyancy tank, situated about the middle of the vessel. It is not possible here to go into technical details, but the reader will know that salt water is more dense and thus more buoyant than fresh water; in consequence,



Photos: Imperial War Museum

Almost invisible even from a very low altitude, the twin periscopes of a submarine seen from the air. *Top*—Light gun in action on a vessel of the "E" Class

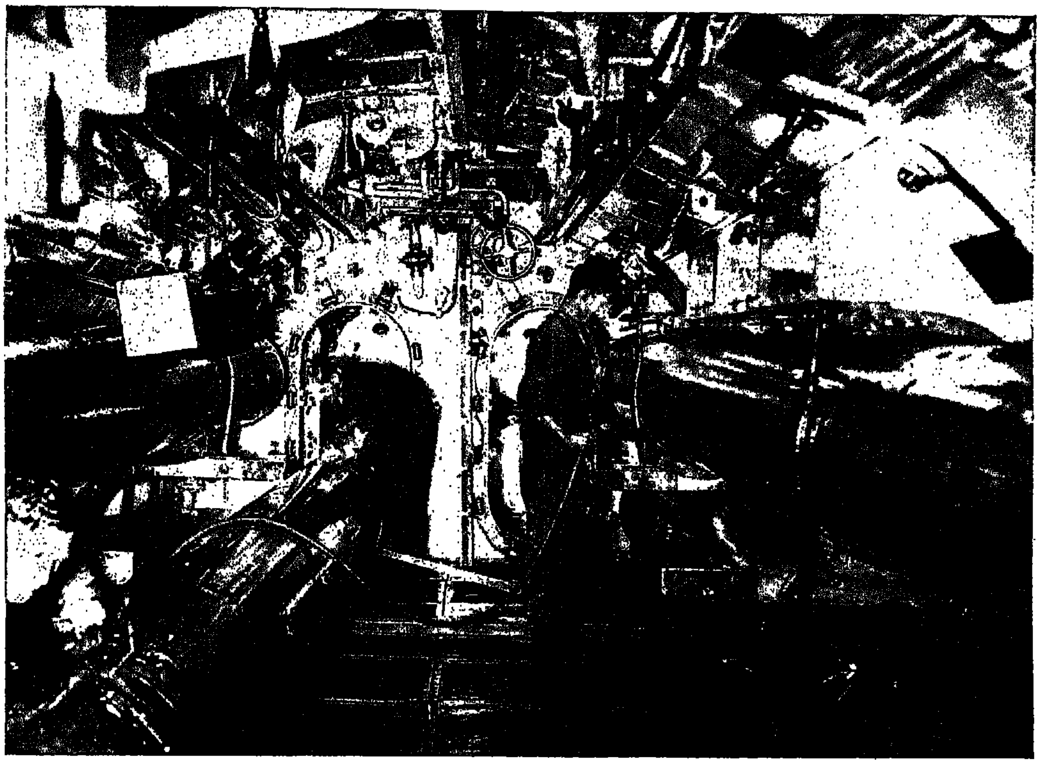
the submarine must take in a greater weight of ballast when submerging in the open sea, and must eject some of this when approaching the mouth of a river, where large volumes of fresh water are mixing with sea water. But for this adjustment of her displacement she would sink lower in the fresher water.

Owing to the need of air (or the oxygen it contains) for combustion in an engine, two quite separate systems of propulsion have to be employed—one for propelling the boat when on the surface and the other when it is submerged. When travelling on the surface Diesel engines are employed. Steam power was used up to quite recent times (1919), with a Diesel engine to come into use just before diving, after which electric motors were brought into operation. For a time—indeed up to 1910—petrol engines were employed in all submarines; but it is almost impossible entirely to control petrol vapour, and in consequence there was always a danger of a serious explosion occurring in the confined space of the submarine. The Diesel engine has several advantages, one of which is that far less weight of fuel is necessary and therefore the submarine automatically has had its radius of action considerably extended. The crude oil used is also much cheaper than petrol and, of course, is not inflammable in ordinary circumstances.

Control room of the British submarine L56 showing officers and men at the diving stations

When a submarine is submerged an entirely different set of apparatus is brought into use. At the present time it is not possible to use Diesel engines or any form of internal combustion motor, because an enormous amount of air is required in operating them and there are the burned gases from the exhaust to be disposed of. The amount of available air in a submarine is so small that it would very soon be eaten up by such engines and, of course, while the boat is under water it is not possible to obtain a fresh supply. Experiments are to-day being carried out both with Diesel engines and with steam turbines for under-water propulsion, and it is possible that at some not far distant date it may be possible to use the same apparatus for propelling the submarine both submerged and on the surface.

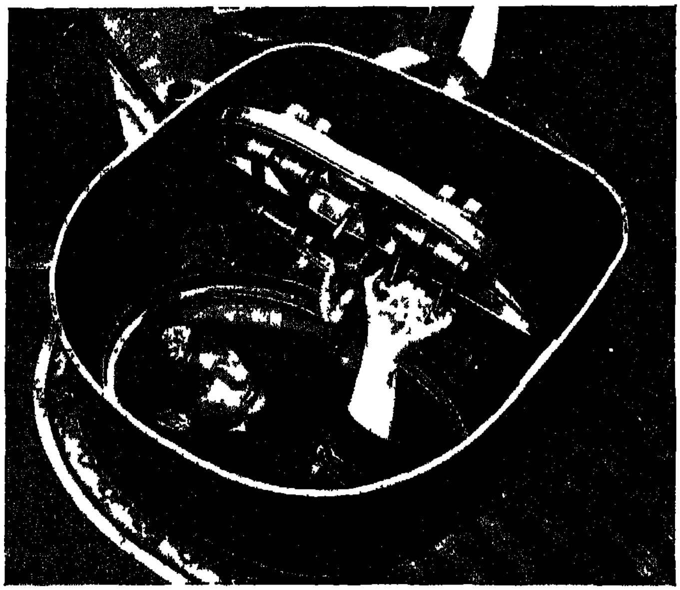
At present the submerged vessel is still propelled by an electric motor, the current of which is supplied from secondary storage batteries. Electrical propulsion has certain advantages which may always recommend it in preference to any other form. One outstanding advantage it has is that it is practically noiseless, and since war vessels are fitted with instruments which can detect the approach of submarines this may prove a deciding factor in the retention of electrical propulsion. It is true that the propeller of the submarine will always be heard, but the operator at the sound detection instrument may not be able to distinguish it from that of any other type of vessel. So far as replenishing the batteries is concerned this is easily overcome; for the same motor that drives the propeller-shaft can be used to



Inside the L 56—The Diesel engine room, looking aft and (*top*) preparing torpedoes. The rating on the right is charging one of the torpedoes with compressed air. Normal working pressure is about 2,000 lb.

recharge the batteries when the vessel is at the surface.

Submarines are steered in the case of large vessels by electrical gear, and in the case of small ones by hand. Indicators showing the direction in which the boat is being turned are fitted in the steering stations and, of course, gyroscopic compasses are employed. The driving controls are operated in much the same way as the steering gear, but a special mechanism is necessary to allow the submarine to remain in one position for any length of time. As a rule a submarine must be continually on the move, but the statical driving gear makes it possible for the vessel to stay for hours quiescent, just below the surface, with only its periscope showing—observing yet unobserved.



About to dive; closing the conning-tower hatch—one of the last acts preparatory to going beneath the surface

How the Escape Hatch Works

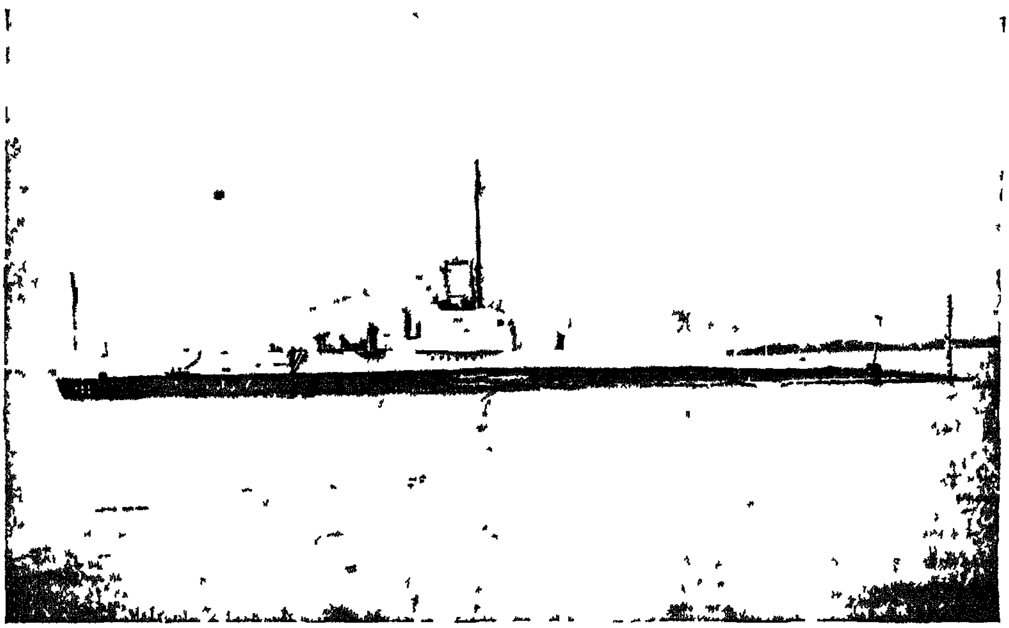
It is natural that a great deal of attention is given to safety devices in submarines, for substantial damage to the vessel may turn it into a death-trap. Every member of the crew is provided with a safety helmet, by donning which he can breathe for several hours either in or out of the water. The apparatus is somewhat similar to a diver's helmet, and the air in it can be used over and over again; the carbon dioxide thrown out by the user is absorbed by a chemical and replenished with oxygen. In order to provide a means of escape from a doomed submarine an escape hatch is fitted as a rule in every compartment. The hatch is in the form of a double-doored compartment; it has an opening giving access to the interior of the vessel and also another opening direct to the sea. Both openings have covers which can be operated from either side. The outer one is, of course, closed and bears upon it the pressure due to the depth of water overhead.

The man who is trying to escape dons his safety helmet and enters the escape hatch, taking care to close the cover behind him. He then turns on a valve which admits water from the sea into the hatch and waits until the pressure inside it is the same as that outside, when he will be able to remove the cover. The buoyancy of the helmet immediately carries him to the surface of the water where he may hope to be picked up. The weakness of this safety arrangement is the danger to the man from the sudden change from the heavy air pressure in the escape hatch to the lighter atmospheric pressure above.

The safety keel is another device which has been favoured. At a given signal this can be released and, since it may weigh anything from five to twenty tons, the vessel, once it has lost such a weight, may rise to the surface if not too much damaged.

One other feature of the submarine must be mentioned, and that is the tube from which the torpedoes are fired. The torpedo itself is a self-contained submarine vessel, able to travel at 40 knots or more. In its head it carries a charge of high explosive. The tube is made of gun-metal and has a cover both on the outside of the vessel and on the inside. Inside it are grooves which act as guides for the fins of the torpedo. The latter, weighing three-quarters of a ton or more, is launched by compressed air usually about 500 lb. pressure; and the tube immediately fills up with water, thus preserving the trim of the vessel. The outside cap is then replaced, the water drained off into a tank and another torpedo inserted in the tube ready for action.

Not until the Great War of 1914 to 1918 was there an opportunity of testing the



H M. Submarine *Shark*—one of the latest British "pocket" submarines capable of a speed of 16 knots and having a range of 4,000 miles on the surface. She can make a "crash" dive in 30 seconds and has roomier accommodation than previous types

value of the submarine as a war weapon, and it came to be used then in a manner not contemplated by most navies—for the destroying of merchant vessels. It has two disadvantages at least which it would appear can never be satisfactorily remedied. In the first place it is blind while under water, except it comes up close to the surface and uses its periscope, which may easily be shot away. Secondly, in spite of its present-day surface speed of 23 knots it is a slow-moving vessel compared with surface warships. Unless the submarine comes on its prey by stealth, the quarry can quickly leave the submarine behind. Moreover, no matter how much faster modern submarines may be made to travel, they will still be in the same position relatively, because surface vessels also will improve in speed. Furthermore, the main advantage submarines have over other vessels—their invisibility from the deck of a ship—is discounted by the use of the seaplane and the flying-boat, whose observer, looking down into the water from an altitude, can detect the undersea vessel even if it be fathoms deep.

Though a German commercial submarine was built and journeyed to America in 1916 to fetch much-needed commodities, no practical peace-time use has yet been found for such a vessel. It is too costly to construct for anything but war purposes, and would have no advantage over an ordinary merchantman.

WONDERS OF THE LAND

Wonders of Nature's Building, Dwarfing the Greatest Works of Man. Geysers, Hot Springs and Volcanoes. Earthquake Terrors. Lakes of Pitch and Seas of Salt. Mighty Rivers and Majestic Falls Yielding Inexhaustible Power. Canals that Link up Oceans. Weird and Curious, Beautiful and Deadly, in Nature's Creatures. When the World was Young. Largest Plants of All. Insect Foes and Insect Benefactors. The Chemist's Gifts to Man. Marvels of Transport, by Air, Land and Sea. Stupendous Engineering Feats

CHAPTER IX

GREAT MOUNTAIN TOWERS OF THE WORLD

MOUNTAIN scenery is regarded as among the grandest in the world and mountainous countries, Scotland and Switzerland for example, are much visited by pleasure seekers. This is, of course, entirely a modern development, being due partly to the appreciation of the beautiful in Nature that was aroused by Wordsworth and Rousseau towards the end of the 18th century and partly to the facilities for travel that enable us to reach most parts of the world in very short periods of time.

Primitive man, as far as we can tell, was more impressed by the terrors of the mountains than by their beauty. He knew that it was dangerous to journey among them, for if he were not killed by wild beasts he would probably, after having lost his way among the trees and shrubs, die of hunger and cold. This feeling of terror at the sight of a mountain was doubtless one reason why some of them were regarded as the homes of the gods.

Mountains associated with Gods

The Greeks made Mount Olympus the principal seat of their deities and from there Jove launched his thunderbolts and despatched his messengers. Mount Ida, in Asia Minor, was also associated with the gods who, according to Homer, were there at the time of the siege of Troy. The early inhabitants of Germany believed that spirits lived in the Harz Mountains, especially on the peak called the Brocken; and among the Himalayas the Buddhists built shrines to their gods. Fujiyama was one of the sacred mountains of the Japanese; at the other side of the world the ancient Peruvians named some of the peaks of the Andes after their gods, and the Aztecs in Mexico paid similar respect to the great mountains in their land.

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Five Lofty Peaks of the Himalayas

The highest mountains in the world are in the Himalayas, a great range in Central Asia. Here are at least five peaks—Everest, Godwin-Austen, Kinchinjunga, Nanga Parbat and Kamet—that are higher than any others in any part of the world. The highest of the five is Everest, which reaches 29,002 feet, while the lowest, Kamet, is 25,431 feet high.

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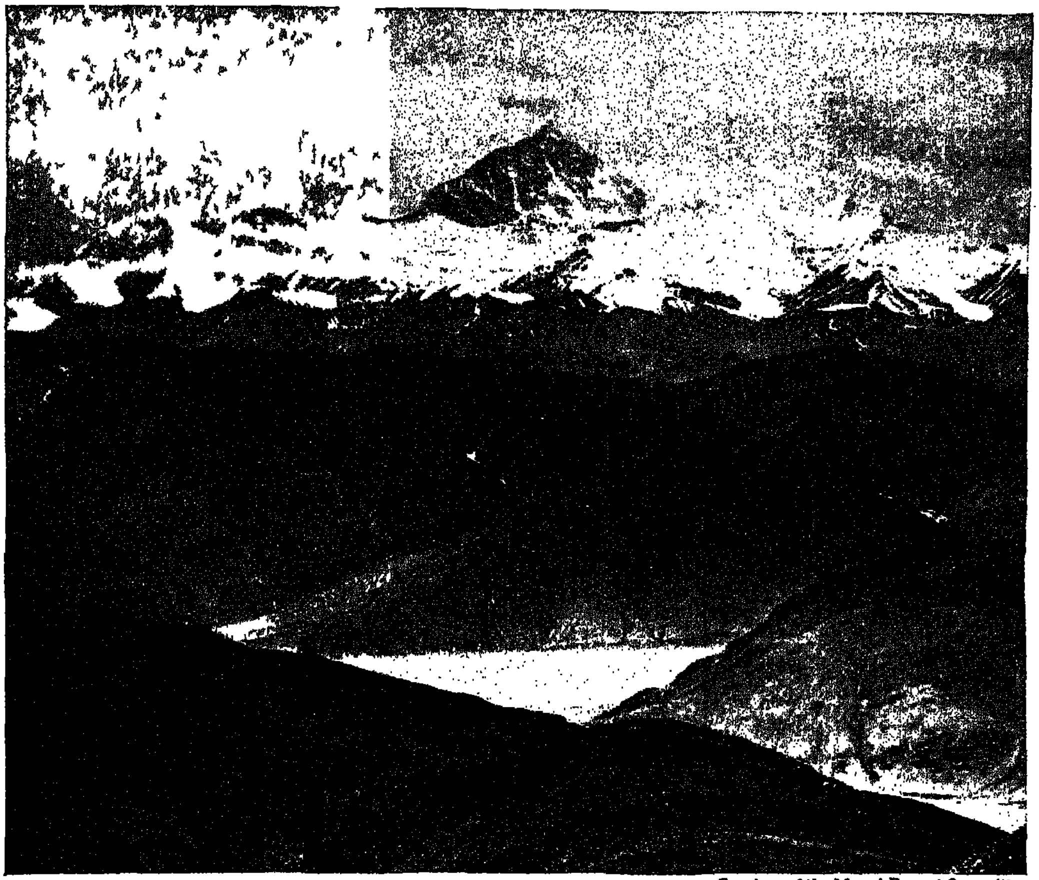
The height of Everest, about five and a half miles, is a very short distance indeed when compared with the size of the earth: in fact, most people walk something like this distance every day of their lives without noticing it. If in the form of a globe an exact representation of the earth was made, Everest would scarcely be seen at all, unless the miniature was of enormous size, for five and a half miles is only one part in 5,000 of the circumference of the earth. If, for example, the globe was made a



Courtesy of the Mount Everest Committee

Proud, remote and inaccessible—the highest mountain in the world. Mount Everest from the Pangla Pass

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The same writer continues: "The average elevation of the whole of the land of the globe again is very small in comparison with that of the range of the Himalaya. As yet the number of elevations that have been determined are too few to enable any accurate estimate of the mean elevation of all the land above the sea-level to be made; but present knowledge indicates that this may be assumed at about 2,250 feet. If then the greatest height of all on the earth's surface would lie within the thickness of a piece of paper laid upon our supposed globe, a thirteenth part of this thickness would nearly represent the average height of the land above the sea-level."

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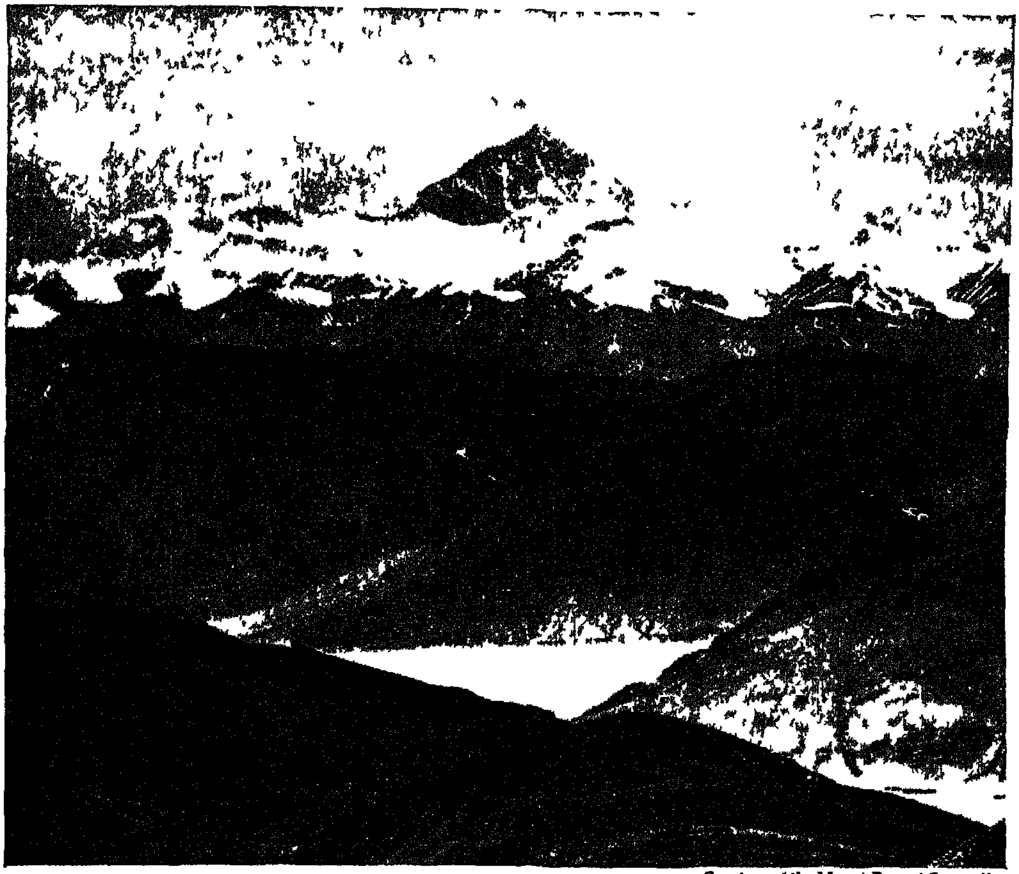

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along the coast of South America for well over 4,000 miles. Passing the isthmus of Panama the high volcanoes of Central America would come into view; next, the high western edge of the tableland of Mexico; then the mountains of California and finally those in Alaska, dominated by Mount McKinley and Mount St. Elias, the peak of which can be seen fifty miles out at sea.

He would be guided by the chain of volcanoes of the Aleutian Islands to the mountains of Kamchatka, the mountains of Korea and the range which forms the eastern slope of the great Asiatic tableland. Proceeding south he would see the mountain ranges of China and, when in the Indian Ocean, he would approach the base of the Himalayas. Passing round the coast of Africa he would see Kenya and Kilimanjaro, and in the south would reach the Drakenberg Mountains in Natal and the terraced ranges of Cape Colony.

Tablelands of South America

Returning to the New World our imaginary traveller would find, if he climbed the steep slope of the Andes from the Pacific shore and crossed the range by one of the passes, that he was on the high tablelands—it may be of Bolivia, of Peru, or of Ecuador —that are supported between the lines of the Cordilleras at an average elevation of 12,000 feet above the sea.

Behind the Sierra Madre of Mexico he would find himself on the great tableland of Anahuac, everywhere about 7,500 feet above sea-level. Farther north across the Sierra Nevada, or the Cascade Mountains, he would reach the great plateau of the western part of the United States, a region which spreads out to the ranges of the Rocky Mountains, which support it on the landward side.

Making a similar journey in Asia he would find, if he climbed the Himalayas or the Khinghan Mountains, that he was on the great plateau of Tibet, where rivers are navigated at an elevation of 14,000 feet above the sea. As he advanced into the interior of the continent he would find that the land remained high until the ranges of the Altai and Thianshan Mountains were crossed, when it would sink into the low plains of Siberia. If he climbed the steep edge of the mountains that rise from the Red Sea he would be on the high plateau of Abyssinia, where the plains are 7,000 feet above the level of the sea. Crossing the opposite border of that land he would descend to the valley of the Nile and the lowlands of the Sudan, which latter extend all the way to the Niger and the Atlantic.

Regarding the Himalayas from the southern, or Indian, side, they appear to rise in a series of steps. First of all is a damp and forested region called the tarai, and behind that is the bhabar, a long and comparatively narrow strip of scrub. These outworks of the system are sometimes called the sub-Himalayas. Behind them are the outer Himalayas, separated from the outworks by valleys. They rise to about 8,000 or 9,000 feet, but in one district are as high as 15,000 feet. Among these hills are the stations to which many Europeans go in the hot weather. They include Simla, Dalhousie, Naini Tal and other places. There too is Darjeeling.

Behind these hill stations, but still many miles away, rise Mount Everest and the great peaks of the Himalayas proper. Their average altitude is about 20,000 feet, but a glance along the range will show that there are groups of giants that exceed that height. The centre of one of these is Nanga Parbat, that rises abruptly from the valley of the Indus, where it is only 3,000 feet high, to over 26,000 feet.

Another group will be found along the deep gorge that the River Sutlej has made for itself through the Himalayas. Nanda Devi, the highest mountain wholly in the British Empire, may be regarded as the centre of this group, though there are others as high or even higher. This group is famous for its glaciers, and herein rise the streams that make the holy river Ganges. Perhaps for this reason the Brahmins have given its chief mountain a sacred character. The third and greatest of these groups is the one that contains Everest and Kinchinjunga. It lies between the River Sutlej and Bhotan.

The Plateau of Tibet

Thus, while the southern front of the Himalayas faces India, into which they may be said to descend by a series of steps, the northern front faces Tibet. There the range falls to about 15,000 feet, from which it rises again to about the same height, thus forming two chains of mountains, sometimes known as the southern and the northern Himalayas. The northern range is separated from the great plateau of Tibet, on which is the mountain fortress of Lhasa, by the valley of the Tsangpo, a river that falls from 15,000 feet to little more than 500. Across this valley the Himalayas become merged in the plateau.

Courtesy of the Mount Everest Committee

A magnificent view of Mount Everest clad in everlasting snows, taken from a point on the great Rongbuk Glacier—(seen winding its impressive way across the foreground) —9 miles N.W. of the peak

A remarkable feature about the *Himalayas* is the height at which the soil is fertile. The tea plant will grow everywhere along the southern slopes to an altitude of 5,000 feet. Trees flourish, grain is cultivated up to 11,000 feet and shrubs grow up to 15,000 feet, while there is pasturage for cattle at 18,000 feet. Snow falls regularly every winter at about 6,000 feet, but the line of perpetual snow is about 15,000 feet. This means that, as nearly all the passes are about 18,000 feet high, transport is difficult and trade between India and Tibet not very extensive. In the last 10,000 feet or thereabouts glaciers abound and avalanches are frequent.

The Challenge of Mount Everest

Mount Everest is in Nepal, rather nearer to the eastern than to the western end of the chain, and can be seen towering into the sky from a great distance away. Little, however, was known of it before 1922 when an expedition went out from England to climb it. Before telling of this it will be interesting to give the impressions—strangely different though they are—of the two Englishmen who in 1924 got to a height of over 28,000 feet. They were Lieut.-Col. E. F. Norton and Howard Somervell, and the descriptions are from Sir F. Younghusband's book, "The Epic of Everest."

Norton says: "The view from the great height was disappointing. From 25,000 feet the wild tangle of snowy peaks and winding glaciers, each with its parallel lines of moraines like cart tracks on a snowy road, was imposing to a degree. But we were now high above the highest mountain in sight, and everything below us was so flattened out that much of the beauty of outline was lost. To the north, over the great plateau of Tibet, the eye travelled over range upon range of minor hills until all sense of distance was lost, only to be regained on picking up a row of snowpeaks just appearing over the horizon like tiny teeth. The day was a remarkably clear one in a country of the clearest atmosphere in the world, and the imagination was fired by the sight of these infinitely distant peaks tucked away over the curve of the horizon."

Somervell writes: "The view from the topmost points that we reached, and, indeed, all the way up, was quite beyond words for its extent and magnificence. Gyaching and Choyo, among the highest mountains in the world, were over 1,000 feet beneath. Around them we saw a perfect sea of fine peaks—all giants among mountains, all as dwarfs below us. The splendid dome of Pumori, the finest of Everest's satellites, was but an incident in the vast array of peak upon peak. Over the plain of Tibet a distant range gleamed 200 miles away. The view, indeed, was indescribable, and one simply seemed to be above everything in the world and to have a glimpse almost of a god's view of things."

For some years after 1841 it was believed that Everest and an adjacent mountain called Gaurisaukar were one and the same; and such was the opinion of two Bavarian mountaineers, Adolph and Robert Schlagintweit, when, in 1855, they climbed to the great height of 22,000 feet. Later observations, however, have proved that the two are quite distinct and that Everest is some 5,000 feet higher than its western neighbour.

For nearly fifty years men have discussed the possibility of reaching the top of Everest and since the World War several expeditions have gone out for this purpose. In 1921 a preliminary expedition was sent out, and in 1922 the first serious effort was made to scale the summit. It failed in its main object, but a good deal of valuable information was gained and on May 20, 1922, man first set foot on Everest, for previously no one had been within 40 miles of it. A little later two of the climbers reached 27,235 feet—something like 3,000 feet higher than any previous climb in any part of the world. The two were Col. Charles G. Bruce, leader of the party, and George Finch.

The 1924 Expedition

Inspired by the results the explorers decided to make another effort in 1924. As on the previous occasion the government of Nepal refused to allow them to traverse that country; so, instead of approaching the mountain by the nearest route, they made a long detour from Darjeeling and reached it on the northern or Tibetan side. At Tingri, in Tibet, they entered upon the difficult part of the climb. Everest, of which they had now a magnificent view, was only 44 miles away, but there were intervening ridges between them and their goal and they had to cross the immense glacier called Rongbuk where, at 16,000 feet, the Buddhists had established a monastery; there they were received with great cordiality and prayers were offered for their success. They established a base camp 16,500 feet up the mountain, and two of the party went up to the

glacier and found themselves only 16 miles distant from the summit of Everest.

The route to be taken on those last difficult miles, over the snow and ice in intense cold and continuous wind, had been decided upon by the most experienced mountaineer of the party, Gerald Leigh Mallory, on his previous climb. Preparations were made, but the first attempt failed, although the two climbers, Norton and Somervell, reached 28,000 feet. A second was made by Mallory and Andrew Irvine who, on June 7, left the topmost camp after saying farewell to their comrade, N. E. Odell, who had come thus far with them. They were never seen again. They may have reached the summit and have met with a fatal accident on the descent, but it is more probable that they fell as they were making their way upwards. A false step in the snow or a failure of the oxygen apparatus may have caused their deaths; no one knows.

In 1935 another expedition was organized, its leader being Mr. Hugh Ruttledge; but this time the attempt to reach the summit was foiled by the early coming of the monsoons. Under the same leadership a larger party set out in the spring of 1936 and high hopes were formed of its prospects of success.

"Five Treasure Houses of the Great Snows"

On the other great peaks of the Himalayas conditions are very similar—luxuriant vegetation on the lower slopes with glaciers and intense cold near the top. Kinchinjunga is the nearest to Everest, being only 75 miles away. The word means the five treasure houses of the great snows, for it has five peaks. A magnificent view can be obtained from Darjeeling, only 40 miles away; but in May 1924, Brig.-Gen. C. G. Bruce, climbing Mount Everest, got one far more remarkable. Says Sir F. Younghusband: "Kanchinjunga," for he adopts this spelling of the name, "is usually hidden by the nearer ranges, and when a ridge is reached from which it should be seen is hidden in mists. But on this occasion Bruce had a rare view of it. From the minor Kapup Pass he saw the whole Kanchinjunga massif. And it was not staring blatantly at him in cold, sharp outline; it was suffused in that mysterious haze so characteristic of this region, a deep bluey-violet haze which gives to even solid mountains a spiritual effect. The lower slopes were swallowed up in blueness, while all above the snow-line seemed to be detached from any earthly base and to be floating in mid-air." The mountain was explored in

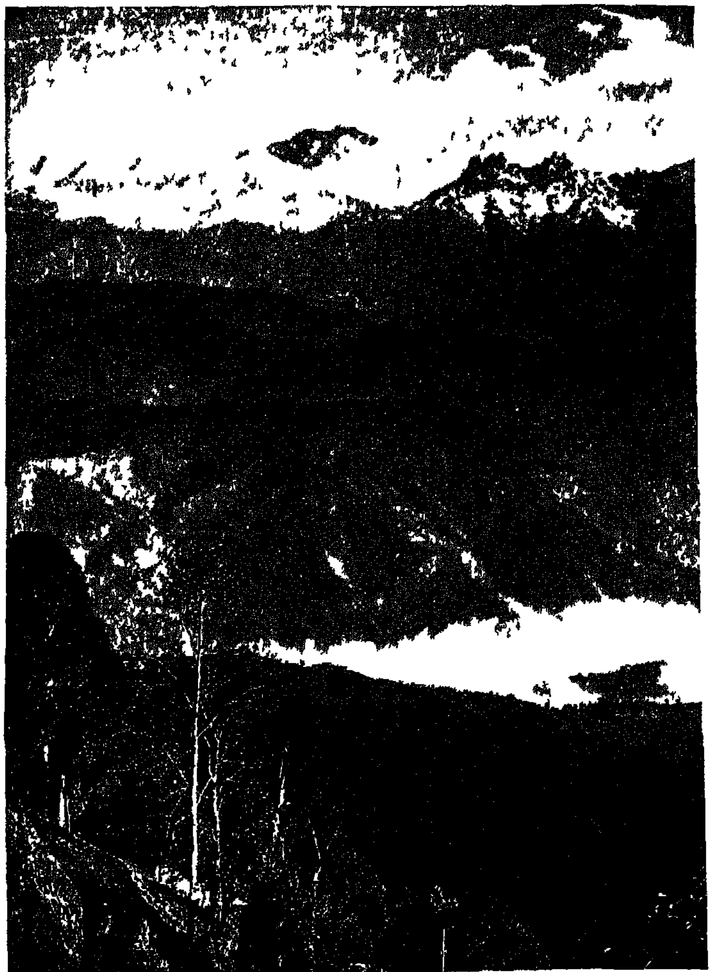


Photo the late H. G. Ponting

Seen across a wonderful vista of intervening ranges and looking its name—Kinchinjunga—"Queen of the Himalayas"

1929–30, but the climbers failed to reach the summit.

Godwin-Austen, also called Dapsang, is in the western section of the Himalayas. It and Kinchinjunga were competitors for the honour of being the second highest peak in the world. For some time it was believed that Godwin-Austen was the higher by 104 feet, but a survey carried out by Col. S. G. Bernard and his staff reversed this judgment by making Kinchinjunga 34 feet higher than its rival. Godwin-Austen was long known simply as K2, this mark being given to it on the survey maps; but, after parts of the range had been explored by H. H. Godwin-Austen, it was given his name.

Nanga Parbat, or the naked mountain, is so called because, unlike the other peaks, it is bare of snow; this is not due, however, to the absence of cold but to the extreme steepness of the sides, which rise almost sheer up from the Indus, as, to compare small with great, the west end of the cathedral at Durham rises from the Wear. The Indus makes a great bend round the mountain, which was long regarded as, if possible, more difficult to climb than the other Himalayan peaks, but in 1932 members of a German-American expedition got some way up it. Kamet, lowest of the five great peaks, was actually climbed, after nine unsuccessful attempts, in 1931, and the leader of the party, F. S. Smythe, rightly called his book describing the ascent "Kamet Conquered."

Urals, Altai and Caucasus

Asia possesses many mountain ranges that, although not equal to the Himalayas, are by no means inconsiderable when judged by any other standard. The Ural Mountains, although like the Caucasus range partly in Europe, may be described here. The central ridge can be traced from between the Lake of Aral and the Caspian Sea to the northern end of Novaia Zembla, a distance of 1,700 miles, but as a chain it really begins on the right bank of the Ural river, at the steppes of the Kirghiz, and runs due north in a long narrow ridge to a gulf of the Kara Sea. In the south the chain is about 100 miles broad, consisting of parallel ridges, the average height of which is about 3,500 feet. The northern section is more lofty; some of the peaks are well over 5,000 feet high and its average height is about 3,000 feet.

About 400 miles from the Urals begin the Altai Mountains, that run for the enormous distance of 4,500 miles through Siberia and Mongolia to the Pacific Ocean, beginning near the Irtish river and ending at the Gulf of Okhotsk. The breadth of this range, which has distinct names for its various sections, varies between 400 and 1,000 miles, save where the desert of Gobi contracts it to 150. Its highest point reaches 14,600 feet, but most of it is below the 6,000 feet level.

Asia Minor and much of Persia are mountainous, and with them may be mentioned the Caucasus region. The lofty range of the Caucasus Mountains, which extend in an unbroken line from the Black to the Caspian Sea, presents much magnificent scenery and the great peaks shoot up from their bases in walls of rock and ice. Forests clothe the sides of the peaks and reach heights of over 7,000 feet. The snow line varies from 11,000 to 12,000 feet, and glaciers are frequent. The highest peaks are Elburz (18,526 feet) and Kasbek (16,545 feet) in the centre of the range, but there are several others between 15,000 and 16,000 feet high.

West and south of the Caucasus are the mountains of Asia Minor or Anatolia. Along the southern shores of the Black Sea stretches a triple range of limestone mountains 6,000 or 7,000 feet high, divided from each other by narrow and beautiful valleys. This high land is bounded on the south by the Taurus Mountains which, beginning in Rhodes and other islands of the Mediterranean, fill the south-western parts of Asia Minor. Farther inland is Armenia, mainly a treeless plain, 7,000 feet above the sea, with Ararat, the mountain of Noah, rearing its twin peaks to a height of 17,000 feet.

The mountains of Persia extend along the northern edge of the Armenian plateau, almost parallel with the shores of the Caspian Sea, maintaining a considerable elevation with the peak of Demavend as their highest point. This great mountain, which is only 45 miles from Teheran, exceeds 18,000 feet, making it one of the great peaks of the world. Spurs of these mountains cover the volcanic tableland of Azerbaijan, the most fertile province of Persia, and the vegetation at their foot has the exuberance of a tropical jungle.

Towering Peaks of the Andes

Excluding the Himalayas the world's highest mountains are in South America in the range called by us the Andes, but by those who live nearer to it the Cordilleras. In it are at least ten peaks over 20,000 feet high, although no one of them reaches the 25,431 of Kamet. There is some doubt

about the exact height of some of these peaks and therefore some difference of opinion as to their order of precedence. It was long believed that Aconcagua, which is certainly the best known, was also the highest, but some authorities say that two peaks in Bolivia—Illampu (or Sorata) and Illmani—are higher. One work of reference gives the respective heights as follows: Illampu 25,248 feet, Illmani 24,633 feet, and Aconcagua 23,025 feet.

On this matter Sir Martin Conway, who climbed Aconcagua in 1900 and wrote an account of his exploit in 1902, says: "In South America extraordinarily exaggerated altitudes have been ascribed to Sorata and other peaks in the Bolivian Andes, misunderstanding having been caused by setting down their measurements in Spanish feet and comparing them, without reduction, with the measurements in English feet of the great Asiatic mountains. I have proved by careful triangulation that none of the Bolivian peaks are as much as 25,000 feet high. At present, therefore, Aconcagua is the highest measured peak in the Andes. It is possible that the great Coropuna peak in Peru may be equal, or even superior, in altitude to Aconcagua, but it has not been measured. We only know that mountains of 20,000 feet, fifty miles farther south, and therefore farther from the equator, are clear of snow in summer, when Coropuna can still be seen raising its immense calotte of snow and glacier apparently 3,000 feet or more above the snow-line."

The Andes extend almost from one end of South America to the other, a distance of 4,400 miles, and run roughly parallel to the Pacific coast. Like that of the Himalayas the soil is fertile on the lower slopes, and there is grass for the llama and the vicuna at considerable heights, but the summits are covered perpetually with snow.

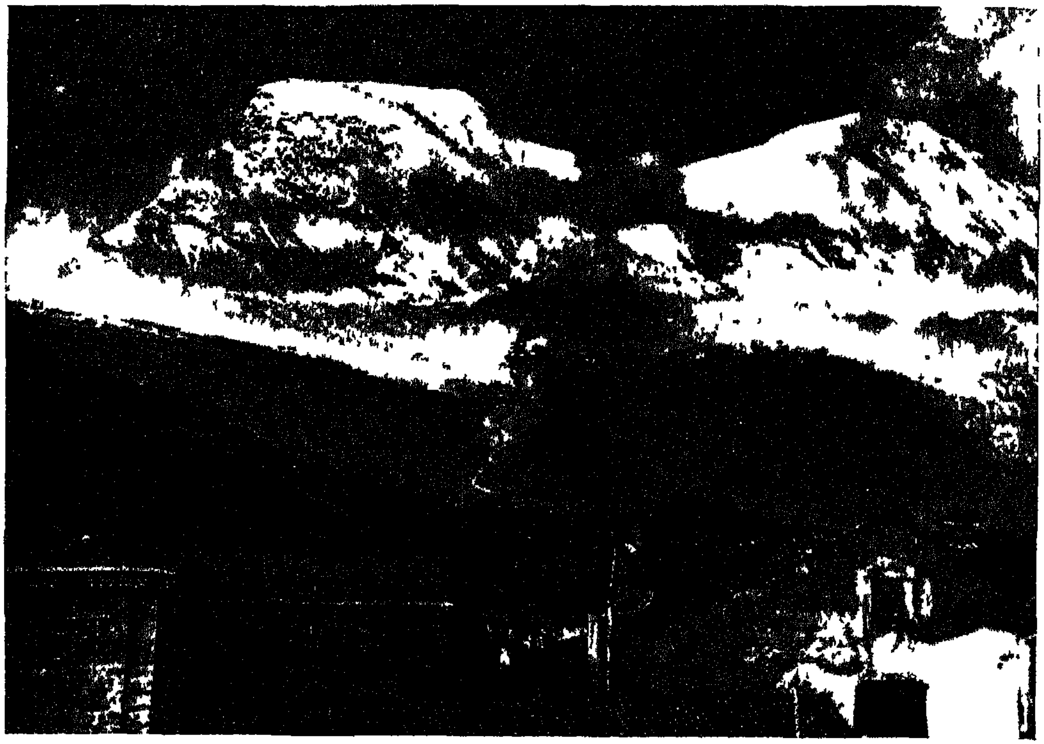
Aconcagua—perhaps the highest mountain in South America—is situated on the boundary between Chile and the Argentine. Here is a view taken from the Transandine Railway

Starting in Colombia in the north the Andes split into four ranges, between which flow three great rivers. The peaks here, mostly volcanoes, rise to 18,000 feet or thereabouts, something like 3,000 feet above the snow-line. Two of these four ranges pass into the next country—Ecuador—where are Chimborazo and Cotapaxi, the highest active volcano in the world. Several of the mountains of Ecuador fall little short of 20,000 feet in height, and from them rise many of the streams that help to form the *greatest river in the world—the Amazon.*

In Peru the eastern and the

Cordilleras continue, but there is also another range known here as the Central. Here the 20,000 feet height is reached by at least four summits, Huascaron, Huandoy, Coropuna and El Misti; and here also the waters run from the mountains to form tributaries of the Amazon. In the south of Peru the central Cordilleras disappear, leaving the other two ranges to enclose the great lake called Titicaca, which is 12,600 feet above sea-level and covers 5,500 square miles. The general height of the Andes in Bolivia, where they have been described by a traveller, Mr. C. P. Enock, as "one of the most impressive mountain masses of the globe." Here are the lofty Illampu and Illmani, while another, Huaini-Potosi, is over 20,000 feet high. The eastern and western Cordilleras pass from Peru into Bolivia, but the great mountains mentioned are in the Cordillera Real, a group in the northern part of the eastern range.

In Chile the Andes form one main chain. The system here approaches much nearer



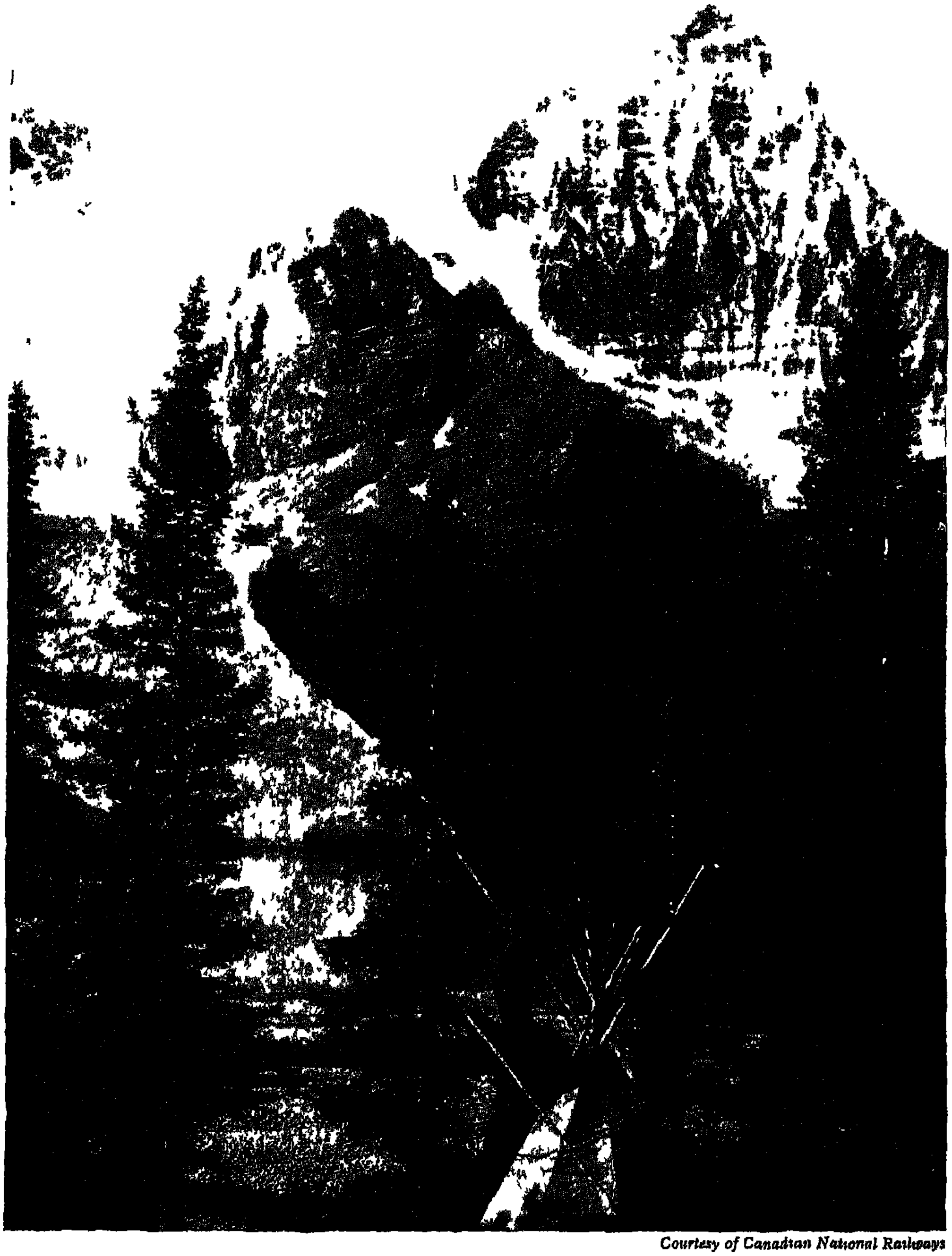
Photo, Schneider

The twin peaks of Huascaron—loftiest in the Peruvian Cordilleras—seen across the Santa Valley from Yungay

here is so great that the only gap in the chain, as far as Peru is concerned, is 7,000 feet high.

Of these Peruvian Andes, Huascaron, named after one of the gods of the Incas, is a particularly noble sight. Its altitude is 22,051 feet and it is on the eastern or main branch of the Andes, with Huandoy, only a little lower, as a neighbour. Here, during the rainy season, the sky is generally clear at dawn, and the magnificent peaks, crowned with snow, are then best seen in all their beauty. As the day advances the clouds collect and the view becomes obscured.

The Andes reach their utmost grandeur the coast, and for about 1,500 miles forms the boundary between Chile and Argentina, decreasing in height as it nears the southern end of the continent. Partly in Chile, but with the other part and also the actual summit in Argentina, is Aconcagua, an extinct volcano. It was climbed for the first time on January 14, 1897, by a Swiss guide, Mattias Zurbriggen, and a few weeks later by Mr. Stuart Vines and a guide, Lanti, all members of the same expedition; in 1900, as we have seen, Sir Martin Conway ascended it, taking a more direct route and unencumbered by instruments of any kind. Of the other peaks of the Andes, Chimborazo was



Courtesy of Canadian National Railways

Mount Robson in the Canadian Rockies, which rises to a height of 13,700 feet, overlooks the Yellowhead Pass on the boundary between Alberta and British Columbia

climbed as far back as 1802, and Cotapaxi in 1872, but most of them are still unconquered.

The view from the summit of Aconcagua has been described by Conway: "To the south was Tupungato, a majestic pile of snow, over which even more majestic clouds were presently to mount aloft. To the north was the still grander Mercedario, beheld round a flank of the final rocks. In the west were the hills dropping lower and lower to the Chilean shore and then the purple ocean. To the north-east, like another ocean, lay the flat surface of the Argentine pampas. Elsewhere the Cordillera, in long parallel ridges, running roughly north and south, stretched its great length along, crowding together into an inextricable tangle the distant peaks, partly hidden by the two near summits which alone interrupted the completeness of the panorama."

Some Notable Peaks of the Rockies

In North America the Rocky Mountains correspond to the Andes, both running more or less parallel to the Pacific coast for about 4,000 miles. The highest peaks are in the north, although the group of mountains in Alaska are not regarded by some authorities as part of the Rocky Mountains proper. However that may be, Alaska contains Mount McKinley, the highest peak on the continent, that rises to 20,300 feet, and Mount St. Elias, the scene of some remarkable mountaineering feats, only about 2,000 feet lower, while quite near the latter, although over the frontier in Canada, is Mount Logan with about the same height.

The Canadian Rockies are mainly in British Columbia, which is by far the most mountainous province of Canada. There the highest mountain is Mount Logan, which has just been mentioned, and another notable one, though about 3,000 feet lower, is Mount Fairweather. Two others are Mount Robson and Mount Assiniboine. Mount Robson is on the borders of Alberta, overlooking the famous Yellowhead Pass, and Canadian pleasure-seekers and mountaineers visit the district in the holiday season.

Outside the Rockies the highest of the North American peaks are in Mexico. The

Photo: Royal Canadian Air Force: Crown Copyright

A wonderful air view of the Canadian Rockies with Mount Assiniboine towering in the middle distance. The mountain takes its name from a Red Indian tribe—the Assiniboins

Photo · American Colony, Jerusalem

An unusual telephoto view of the great African peak, Mount Kenya, which has twin summits and is 17,040 feet in height

famous volcano Popocatapetl reaches 17,520 feet and Orizaba, called by the Aztecs Citlaltepetl, or the "star mountain," has about the same altitude.

Kilimanjaro and Kenya

The third of the great continents, Africa, has no range of mountains quite comparable with the Rockies, the Andes, or the Himalayas. Its highest point is Kilimanjaro, a mountain mass in the territory of Tanganyika, almost on the borders of Uganda. It consists of two extinct volcanic peaks, connected by a massive ridge and reaching a height of 19,325 feet. The slopes are covered with forests and the summits with glaciers. On the lower slopes a game reserve has been made.

Another great African mountain—this one in British and not mandated territory—is Kenya. It is 80 miles from Nairobi, from which it can be seen on a clear day, and rises to 17,040 feet. Although only a few miles from the equator, it has fifteen glaciers; but the lower slopes are extremely fertile, while forests cover the middle ones. The summit was reached in 1899 and again in 1929. The mountain was originally a volcano, but its crater has quite disappeared. Like Kilimanjaro it has two summits.

The great mountain mass in Europe is the Alps, but the highest peak on the continent is some hundreds of miles away, in the Caucasus region, near the border-line between Europe and Asia and in the territory of the Soviet Republic; this peak is Mount Elburz, already mentioned, with two peaks, once active volcanoes. Its greatest height is 18,526 feet and it was first climbed in 1829. Tradition says that the ark rested here on its voyage to Ararat.

The best way of obtaining an idea of the extent of the Alps is to study a good map, for they do not form a single chain, but are rather a collection of groups and ranges stretching in every possible direction. The Alps are usually divided into three main groups—western, central and eastern—all radiating from Switzerland. The best known to English travellers is the central group that includes the Bernese Oberland and other familiar districts; but the western, that stretches into France and Italy, is becoming hardly less so. The eastern Alps pass through the Tyrol to the neighbourhood of

Vienna. Each group has its distinctive name, such as the Cottain, Dauphinè, Graian and Pennine Alps in the west; the Lepontine, Todi and Rhaetian Alps in the centre; and the Dolomites, Julian and Carnic Alps in the east. The aveiage height of the Alps is from 5,000 to 7,000 feet above sea-level. The highest peak is Mont Blanc, and the second highest Monte Rosa—both over 15,000 feet. There are scores of peaks between 12,000 and 15,000 feet high.

The Alps stretch into five countries—France, Italy, Switzerland, Germany and Austria. Many passes cross them and through some of these—for example, the Simplon, the Mont Cenis and the St. Gotthard—railways now run. The lowest of the passes is the Brenner, 4,500 feet high, also crossed by a railway line. The Great St. Bernard, the Stelvio and the Furka are other famous passes. These breaches in the Alpine barrier have historic associations: Hannibal led his army across one of them in order to invade Italy, and long afterwards Napoleon did the same. The Barbarians more than once poured through the Brenner on the same errand.

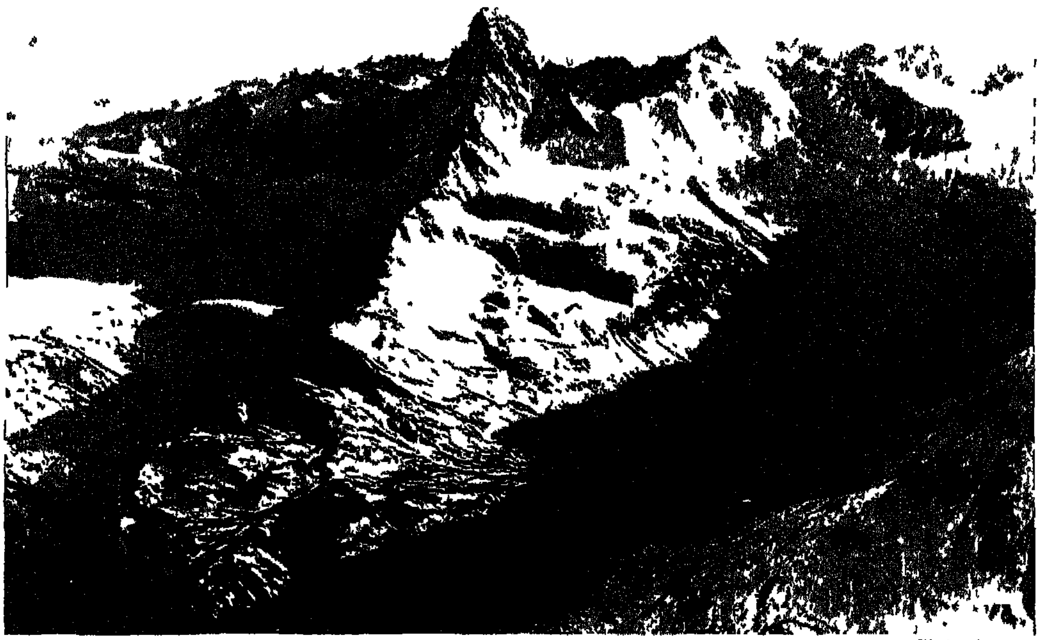
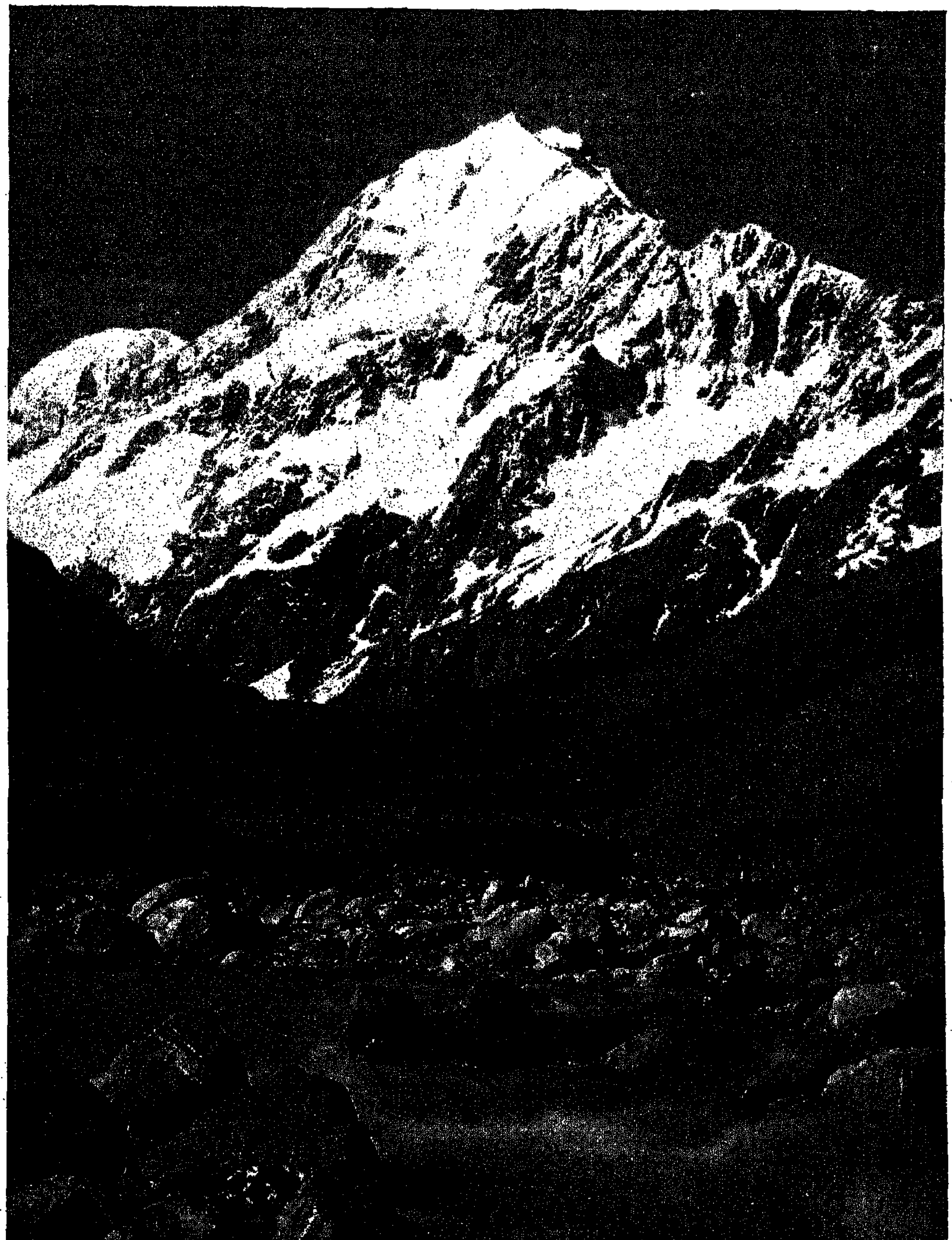


Photo Swissair

The familiar outline of the famous Matterhorn assumes a very different aspect when seen from the air. It is only twenty-five years since the French airman Chavez made the first crossing of the Alps by aeroplane—now a commonplace daily occurrence

Apart from the two highest peaks, the best known of the Alpine mountains are perhaps the Matterhorn, the Jungfrau, the Finsteraarhorn, the Riffel Alp and the Gross Glockner, but there are many others almost as familiar.

Mont Blanc, or the "White Mountain," 15,781 feet high, is situated on the borders of France, Switzerland and Italy, between the Great and the Little St. Bernard. It has several peaks and is best ascended from Chamonix. Monte Rosa is on the border of Italy and Switzerland, 50 miles east of Mont Blanc; it is 15,217 feet high. The Matterhorn, that is also on the borders of Switzerland and Italy, is best ascended from Zermatt; its height is 14,782 feet. Near it is the Weisshorn, almost exactly the same height. The Wetterhorn, only 12,166 feet, is near Grindelwald. Another mountain very popular with climbers is the Jungfrau or the "Maiden." This is wholly in Switzerland and has a height of 13,670 feet. In the eastern section of the Alps the highest mountain is the Glockner, 12,455 feet. It is in Austria, in the range called the Hohe Tauern, and its two peaks are known as the



Courtesy of the New Zealand Government

Topmost pinnacle of the Southern Alps of New Zealand—majestic Mount Cook—12,349 feet high, viewed from the Hooker Valley

Gross and the Klein Glockner, the latter being about 100 feet lower than the former.

Attempts to climb the Alps were made soon after 1800, and in the 19th century, with the foundation of Alpine Clubs, many persons turned their attention to it, but Mont Blanc had been already ascended by two guides in 1786. In 1854 an Englishman made the first ascent of the Wetterhorn; in 1855 Monte Rosa was climbed; in 1861 the Weisshorn, and in 1865 Matterhorn. Since then almost every peak has been ascended and to-day it is within the power of any able-bodied person to reach the tops. There is a complete service of guides and a regular scale of charges.

Outside the Alps the great mountain ranges of Europe are the Pyrenees, the Apennines, the Carpathians, the mountains of Scandinavia and those of the Balkans. The Pyrenees, which form a natural boundary between France and Spain, maintain a waving line with a mean altitude of 8,000 feet. They are highest in the east where, too, is the highest peak, Pic de Nethou (11,168 feet). The snow lies on these mountains during the greater part of the year and is perpetual on the highest points, but the glaciers are nothing so extensive nor as numerous as in the Alps. The greatest breadth of the range is 60 miles and its length 270. On the French side it is so steep that from the plains below the summits look like the teeth of a saw. On the Spanish side gigantic sloping spurs, separated by deep valleys, extend to the banks of the Ebro. Spain has its own mountain ranges and four of them run nearly parallel diagonally across the peninsula. The highest mountain, excluding the peaks of the Pyrenees, is 10,000 feet high. Outside the Alps the highest peak in France reaches only 6,185 feet.

The Apennines

The Apennines, connecting with the Maritime Alps, run through the centre of Italy to the middle of Calabria, where they split into two branches. The whole length is about 800 miles. None of the peaks rises above the limit of perpetual snow, though snow lies during nine months of the year on the highest of them, Monte Corno, in the Grand Sasso d'Italia (9,590 feet), the great rock of Italy.

The Carpathian range consists of several mountain groups connected with each other by elevated plains. The highest point rises to 9,500 feet, and in the Tatra group there is one of 8,800 feet. Greece is a country of mountains, and to a lesser extent this applies to other lands of the Balkan peninsula. In Greece the several chains end in bold headlands that reach far out into the sea and reappear in the many islands and rocks of the Ægean Sea. These Greek mountains, the highest being over 8,000 feet high, like those in the Balkans proper, are much torn by transverse fractures.

The Mountainous Scandinavian Peninsula

The range of mountains which has given its form to the Scandinavian peninsula begins at Cape Lindesnaes, the most southerly point of Norway, and after running along its western coast 1,000 miles in a northeasterly direction, ends at Cape North The mountains do not form a continued ridge or chain, but constitute a series of broad plateaux, separated at wide intervals by deep and narrow valleys. The most characteristic of these tablelands is the Dovrefjeld, 3,000 feet high, on which Sneehatten rises to 7,566 feet. In the northern and narrower part of the peninsula the Kiolen Mountains assume more the form of a ridge, rising in Mount Sulitelma to 6,150 feet, whence it falls in the north, till at the North Cape it is only 1,500 feet. It has been compared to a huge wave or billow, rising gradually from the east, which, after having formed a crest, falls perpendicularly into the sea in the west. It is estimated that nearly 4,000 square miles of this peninsula rise above the line of perpetual snow.

At the distance of 360 miles from Cape Lindesnaes the mountains form a single elevated mass, terminated by a tableland which maintains an altitude of 4,500 feet for 100 miles. It slopes gradually towards the east and plunges at once in high precipices into a deep sea on the west.

There are many other mountains about which something could be said, but there is only space to mention one—Mount Cook in New Zealand. This is in South Island, and is the highest point in the Southern Alps, for this name has been transported to the Dominions. On it is the great Tasman glacier and it can easily be reached from Timaru, 96 miles away.

CHAPTER X
THE TOWER BUILDERS

BEFORE we look at a few of the outstanding towers of the world, we had better be sure what we mean by a tower. The dictionary defines it as (1) a building, lofty in proportion to the size of its base, either isolated, or forming part of a castle, church or other edifice, or of the walls of a town; (2) such a structure used as a stronghold, fortress or prison, or built primarily for purposes of defence. In this latter sense, so says the dictionary, the name is sometimes extended to include the whole fortress or stronghold of which a tower in sense (1) was the original nucleus. Thus the Tower of London is the entire fortress surrounding the original White Tower of William Rufus.

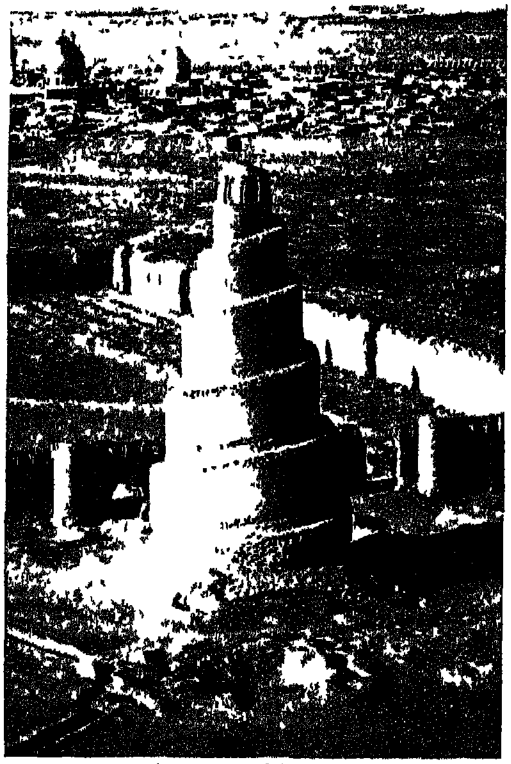
The question why men erect towers has been partly answered by the foregoing definitions. Their reasons may be military, either for defence or refuge; religious, for calling devotees to worship either by bells or by the human voice; scientific, for observation in a clearer atmosphere than on the ground, indicatory, for distant visibility either of themselves or of lights upon them; commemorative, either to honour a hero or to mark a notable spot; economical, because space to build laterally is not available; purely decorative or merely vainglorious; or indeed, a compound of two or more of these purposes.

It was apparently the last-mentioned motive that inspired the builders of the Tower of Babel. "They said, Go to, let us build us a city and a tower, whose top may reach unto heaven." For this presumptuousness they were punished by confusion of language, and it is noteworthy that the Hebrew account of the offence and its retribution is matched by similar traditions in other parts of the world—Assam, Ashanti, South Africa and Mexico, but not, curiously enough, in the records of Babylonia, which appears to be the setting of the Biblical story. The actual site of the Tower of Babel, though traditionally identified with Borsippa (Birs Nimrud) outside Babylon, is entirely conjectural. Equally so is the nature of the tower itself, though it is not unreasonable to suppose that it resembled

Photo· American Colony, Jerusalem

The Tower of Babel. ***Left:*** **Reconstruction, based on an account by Herodotus, of a Babylonian tower over 650 feet high and measuring half a mile in circumference at its base.** ***Right:*** **Remains of a ziggurat, with sections of fused bricks, at Birs Nimrud—the traditional site of the Tower of Babel**

the "ziggurats" or staged pyramids, ruins of which have been found in Mesopotamia. These varied both in plan, which was either rectangular or circular, and also in the number and arrangement of the stories, some examples having the offsets in the form of a continuous ramp or spiral round the outside of the building. Herodotus describes one such as "a tower of solid masonry, a



Royal Air Force Official: Crown Copyright Reserved
The Malwiya at Samarra—a Moslem minaret, 160 feet in height, which was copied from a Babylonian ziggurat

furlong in length and breadth, upon which was raised a second tower, and on that a third, and so on up to eight; the ascent to the top is on the outside by a path which winds round all the towers . . . on the topmost tower there is a spacious temple."

The purpose of the ziggurats is uncertain. They may indeed have been surmounted by temples, and some have supposed the spiral ways to have been constructed for the ascent of sacrificial oxen. Others have suggested that they were primarily tombs, like the pyramids of Egypt; and in the tower at Birs Nimrud a vault has been discovered, 100 feet long, six feet broad, and twelve feet high. There is another theory that they were intended to facilitate observation of the stars, a common practice in Babylonia, by raising the observer above the hazy and dusty atmosphere of the plain; the stages, which are known to have been enamelled in different colours, are even conjectured to have been dedicated to the sun, moon and five planets. On the other hand the wording of extant inscriptions points to the vainglorious motive; in one of these Nabopolassar (625–604 B.C.) says he received a divine command as to "the tower of Babylon, which in the time before me had become weak and had been brought to ruin, to lay its foundation firm on the bosom of the underworld, while its top should stretch heavenwards." In another inscription his successor Nebuchadrezzar uses the phrase, "to raise up the top that it may rival heaven," which is singularly reminiscent of *Genesis* xi, 4. It is a remarkable fact that many centuries afterwards the Caliph Mu'tassim (A.D. 833–842), son of Harun ar Rashid, when building his great mosque at Samarra on the Euphrates, deliberately copied the ziggurat type of tower for a minaret, which is still standing under the name of the Malwiya and is estimated to be 160 feet in height.

The Pharos at Alexandria

It does not appear that the genius of the Egyptian builders ever evolved a tower, as we understand the term; their monuments took the form of gigantic pyramids and monolithic obelisks. Neither were the Greeks inspired to construct a "building lofty in proportion to the size of its base." Such inspiration is seldom found in a country dominated by rugged mountains. In their military defences the Romans built towers, probably of no great height, as, for example, the mile-castles and intermediate turrets along Hadrian's Wall. Their outstanding works in tower-construction were lighthouses, the most famous being that on the island of Pharos at Alexandria, erected about 280 B.C. by Sostratus of Cnidus (*see* Colour Plate). This, built of white limestone, is estimated to have been 360–390 feet high and to have risen in several stages, square, octagonal and cylindrical. It was one of the Seven Wonders of the world and gave the name "pharos" to all lighthouses. Most of it fell during an earthquake in A.D. 1303, and the remains were overwhelmed by the sea. The well-known Roman pharos at Dover Castle, octagonal

without and square within, is now of no great height even with its Tudor addition; but on the opposite coast at Boulogne, the emperor Caligula, in A.D. 40, ordered the erection of a triumphal tower, which later became a lighthouse. Under the name Tour d'Odre this still exhibits a few remains; but a picture, formerly at Cowdray House, of the siege of Boulogne in 1555, showed it as a lofty, fourteen-storied tower standing on the cliff and labelled "The Old Man."

It was not till the Dark Ages, after the fall of Rome was well advanced, that men attempted anything ambitious in the way of building; but the demand for stronger castles and statelier churches gradually produced in Western Europe a new style of architecture which has the general name of Romanesque. The building modes of the Eastern Empire also spread to the west, and some of the earliest Italian towers are found in Byzantine buildings; notable among these are the circular "campanili" of the 9th and 10th centuries at Ravenna. The introduction of bells gave a great fillip to tower-construction. It must be remembered, however, that the word belfry has no connexion with the word bell. It was formerly spelt "berfrey," from the Teutonic "berg frid," meaning a defensive place of shelter; and amongst other things signified a movable tower used in sieges, or a pent-house, and even a cattle-shed—a meaning that still survives in Lincolnshire; later it was applied to a watch-tower and then to a bell-tower.

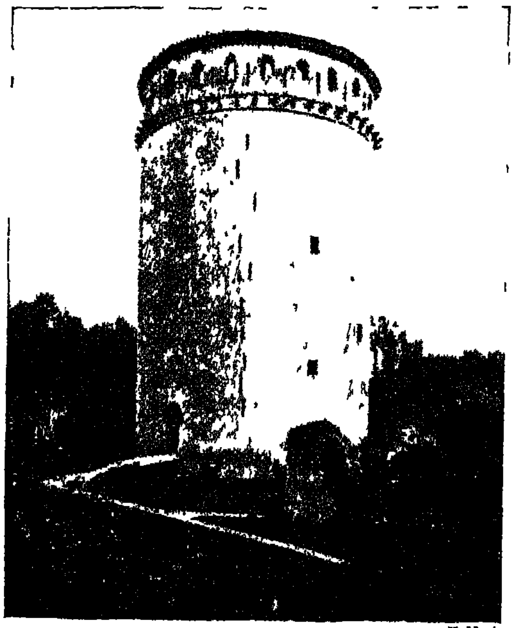
In Italy towers for bells are generally isolated from other buildings. "In plan," says Professor Banister Fletcher, "they are always square and have no projecting buttresses, as on this side of the Alps. They are treated as plainly as possible, without breaks, and with only sufficient windows to admit light to the staircase or sloping way inside; the windows increase in number from one in the lowest story to five or more in the uppermost story, making this stage into what is practically an open loggia, and the whole is generally crowned with a pyramidal-shaped roof."

E.N.A.

Two leaning towers at Bologna: the unfinished Torre Garisenda (left) is 8 feet out of the perpendicular, and the Torre Asinelli 4 feet

The church of S. Zeno at Verona has a fine campanile of the 11th century, with triple arched openings in the two topmost stories. In the tower at Siena cathedral the openings increase from one to six—almost too regularly. The famous leaning tower of Pisa (1172), which is circular in plan, has seven stories of arcades, the upper six of which are so much alike that Ruskin called it the "one thoroughly ugly tower in Italy . . . because it is divided into vertical equal

parts." The foundations of this tower began to give way during the building, but the builders boldly continued their work, slightly diminishing the slant of the upper stories and adding at the summit a turret of smaller diameter to contain the bells; the total height is 183 feet, and the cornice overhangs the base by thirteen feet. There are other instances of Romanesque architects not giving enough attention to foundations. At Bologna there are two brick towers which have a very dissipated appearance: the Torre Asinelli (1109), is 320 feet high and deviates four feet from the vertical; while the unfinished Torre Garisenda close by is 158 feet high, but as much as eight feet out of the straight—a feature that made Dante compare it to the bending giant Antaeus.



E N A.

The mighty donjon at Coucy-le-Château, two-thirds of the diameter of which was taken up by the walls. It was destroyed during the European War, 1914-1918

Norman Towers that Collapsed

In our own country Norman work has sometimes collapsed. In 1322 the central tower of Ely cathedral fell, being happily replaced later by the glorious octagon; and in 1786 the western tower of Hereford crashed down on the nave with disastrous effect. But there are still many fine examples of Romanesque towers on both sides of the Channel. In France it was usual to build a pair of towers at the west end of churches, as at Caen in the Conqueror's Abbaye aux Hommes; though central towers at the crossing are also found, as in his queen's Abbaye aux Dames. Worms cathedral in Germany has twin circular towers at each end as well as a low octagon in the centre, while Tournai cathedral in Belgium has twin square towers flanking the transepts. In the basilica of Sant' Andrea at Vercelli in north Italy there are two thin western towers, a central octagon with a smaller superimposed, and a large isolated campanile on the south side.

In our greater churches in England we have Romanesque (Norman) central towers at Winchester, Norwich, Tewkesbury, and St. Albans (the last named constructed of Roman bricks from Verulamium); a single tower in the middle of the west front at Ely (lower part); a pair of western towers at Durham and Lincoln (lower parts); and a pair curiously placed as transepts at Exeter. Southwell provides a perfect example of a church with both central and twin western towers in the Romanesque style. Parish churches with Norman towers, generally central, are numerous; special mention must be made of the fine tower of Castor church, Northants. In East Anglia many western towers are circular—there is a good example at Little Saxham, Suffolk—this form being adopted owing to the absence of good local stone for building the quoins of square towers.

Towers of Defence

Meanwhile the military architects were developing the tower as a means of defence. Not only were the walls of a castle or a town strengthened at intervals by projecting bastions in the Roman and Byzantine manner, but single towers were erected of such height and mass that they were almost impregnable in the days before the use of gunpowder. In France such a tower was called a donjon, and a circular form was often adopted. There is a fine 12th-century example 150 feet high at Châteaudun, while part of the castle at Amboise on the Loire consists of what Henry James called a colossal cylinder: "it is of astounding size, a fortress in itself, and contains, instead of a staircase, a wonderful inclined plane so wide and gradual that a coach and four may be driven to the top." There is a similar arrangement in the great round tower of Trinity church, Copenhagen (1600).

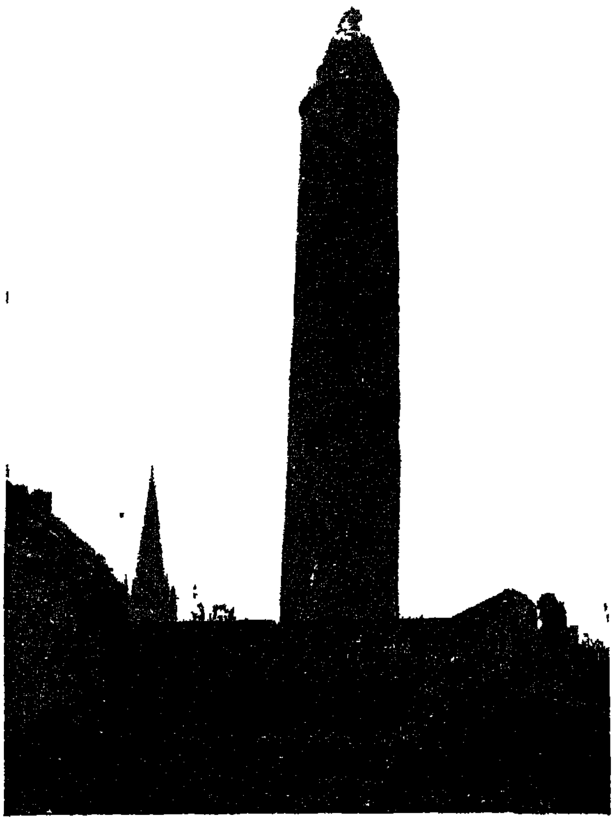
But these paled into insignificance beside the immense circular donjon of Coucy-le-Château, near Laon, with a height of 210 feet and a diameter of 100 feet, two-thirds of the latter being taken up by the walls; well

might the architect Viollet-le-Duc exclaim that compared with this giant the largest towers known appear mere spindles.

In England the Normans perfected the rectangular *keep,* and have left us many massive examples, some in positions of great natural strength, as at Dover in Kent, Richmond in Yorkshire, and Bamburgh in *Northumberland. The Tower of London* has been already mentioned. Of rounded form but irregular plan is the so-called Cæsar's Tower at Warwick, which rises 100 feet from the adjoining courtyard and about another 100 above the Avon. The small but lofty keep at Conisborough castle, Yorkshire, is circular within but has angular turrets outside running up its entire height. The most abnormally planned tower in England is the 13th-century example at Stokesay castle, Shropshire, which may be described as a "Siamese" pair of irregular octagons. This is really a tower-house, like the curious keep at Warkworth, Northumberland (about 1400), which is constructed of unusually fine masonry. As a defensive work the keep had fallen out of fashion by the 13th century, though there is a remarkable "domestic" example of the 15th at Tattershall, Lincolnshire, not to mention Edward III's famous Round Tower at Windsor.

Border Pele Towers and Irish Round Towers

Edward I's castles in Wales were designed as walled enclosures with a crown of turreted towers, circular at Conway and angular at Carnarvon, where the three-turreted Eagle Tower is a striking object above the tidal river. The numerous pele towers of the north of England, which were places of refuge from the marauding Scots, were originally small isolated keeps, though now often found attached to later buildings; those at Chipchase on the North Tyne and at Featherstone on the South may be singled out for special mention. In Ireland the curious round towers, mostly with conical caps, were built primarily for refuge, though probably in some cases intended also for use as bell-towers, as their Irish name "cloichtheach" implies; it is noteworthy that their doors are often raised ten or more feet from the ground. They belong to various dates from the 6th to the 13th centuries, and are about 50 feet in circumference. Perfect examples are found among others at Glendalough (110), Antrim and Cashel (92) and Clondalkin (84 feet high). There are two of these towers at Clonmacnois—O'Rourke's with raised door and McCarthy's with door at ground level—and a very good example adjoins the cathedral at Brechin in Scotland.



W. F. Taylor

Round Tower at Killala, co. Mayo, a perfect specimen of these Irish places of refuge. It is 84 feet in height

It was left for the ecclesiastical architects of the Middle Ages to bring the tower to æsthetic perfection. The coming of the pointed arch introduced what is called the Gothic style, the flexibility of which inspired men to more and more ingenious designs and more and more daring effects. Towers began to soar from all the churches of western Christendom, and the spire was invented to carry the eye still farther up to the heavens. On the Continent there was a tendency to make the churches themselves so lofty that

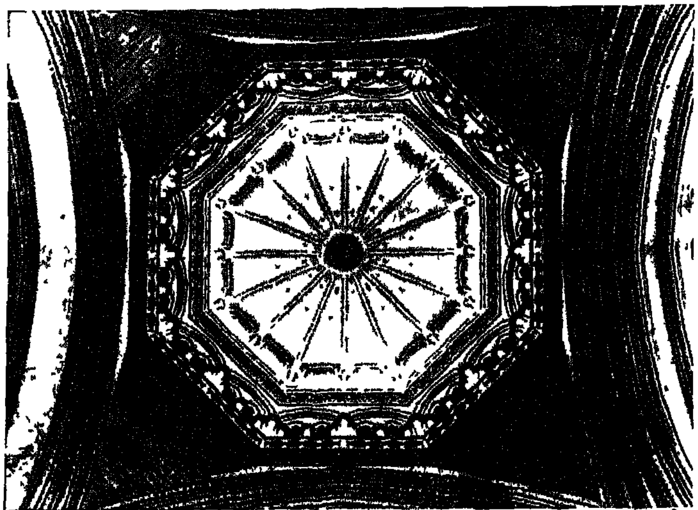


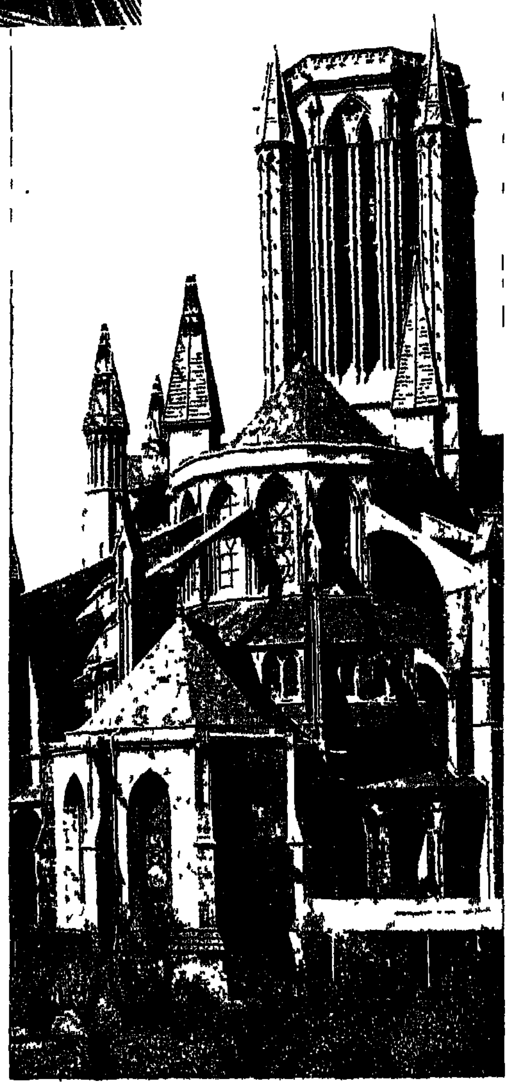
Photo: J. H. Reynolds

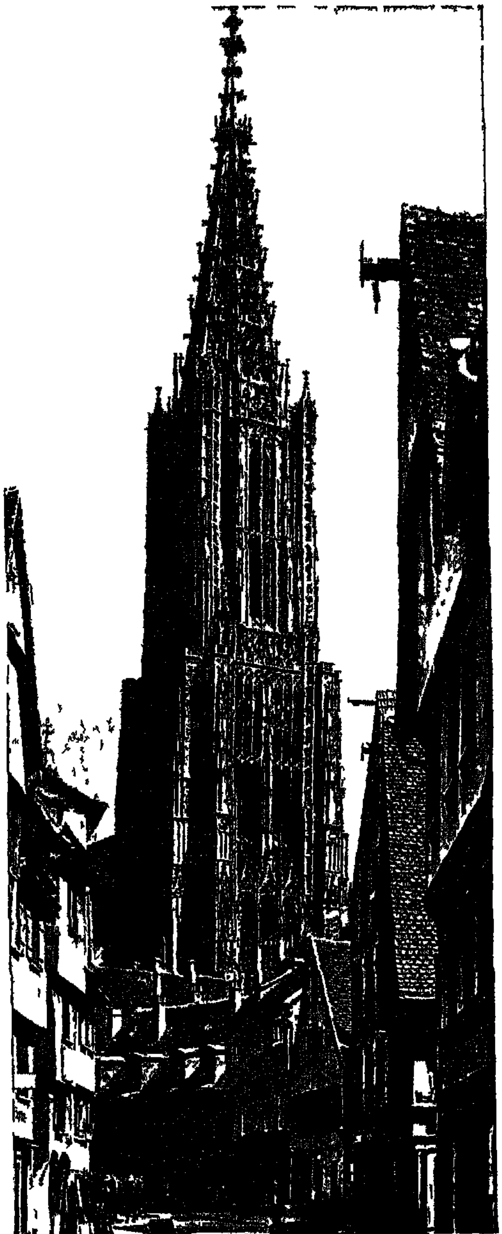
Lofty central church towers are comparatively rare in France. Looking up into the central tower of Coutances cathedral, the exterior of which is seen on the right

they were unable to bear the burden of a tower on the body of the fabric; we find the builders of a cathedral like Amiens content with a light "flèche" at the centre. In our own Westminster Abbey, which was French in conception but English in execution, the piers of the four great arches at the crossing are so bowed that they have never been asked to support anything more than the merest stump of a lantern. Towers were placed at the extremities of a church, generally flanking the western front. At Amiens these are dwarfed by the lofty nave and, like so many pairs of towers on the Continent, are dissimilar in height and design; Bourges cathedral, magnificent in other respects, suffers in the same way.

At Chartres a much grander effect is obtained by spires, the south-western of simple design and 350 feet high, and the north-western a superb creation of the early 16th century and 375 feet high. Laon cathedral was originally intended to have pairs of towers not only at the west end but also at the ends of both transepts, where, however, only one was erected for each. These four towers, 180–190 feet in height and contrasting strongly with the squat central lantern, are of most pleasing design, square below and octagonal above, and their effect is enhanced by their position on a considerable hill; the oxen that dragged the stone up from the plain are commemorated themselves in stone, peering down from the upper stories of the western steeples.

There are of course instances of central towers on French churches. Coutances cathedral in Normandy, also on a hill, has one of noble design, an octagon rising from a square but masked by turrets at the four corners; internally the view directly upwards into this lantern is particularly striking. The western towers were considered by Ruskin to show one of the earliest examples of fully developed spires and "the evident treatment of the church spire merely as a magnificent house-roof." St. Ouen at Rouen is a





Courtesy of German State Railways

The soaring steeple of the minster at Ulm on the River Danube—the highest church spire in the world

remarkable example of a French church with a lofty central tower; it dates from the 14th century and is 260 feet high, including the octagonal open-work lantern called "La Couronne de Normandie," the western spires being 282 feet high. The central tower of the cathedral at Rouen has been disfigured by the erection of a gargantuan iron spire rising to a height of 465 feet. Much more attractive is the stately but too ornate tower on the south-west, which is 252 feet high and crowned with an octagonal lantern, it was built in 1520 and called the "Tour de Beurre" because the cost was defrayed by the indulgence-money paid for the privilege of eating butter in Lent.

One other French tower must be mentioned

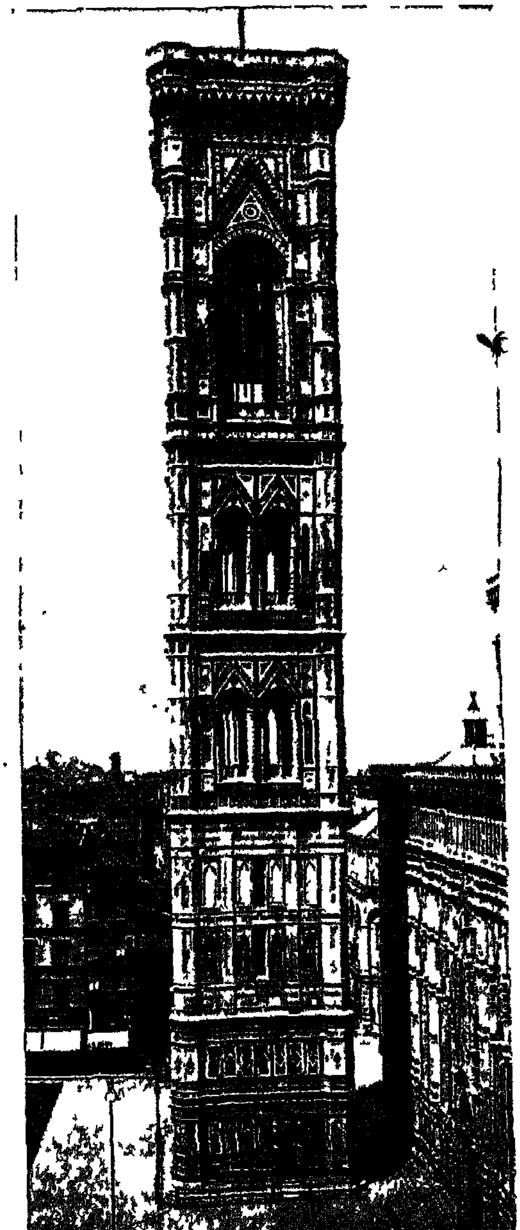


Photo: Alinari

Giotto's Campanile at Florence, considered by Ruskin to be the world's perfect building. It is 292 feet high

and that is the extraordinary erection at Albi, on the river Tarn, some 45 miles from Toulouse. Here the cathedral, dating from the 13th century and constructed entirely of red brick, was intended to serve as a

Photo: J. H. Reynolds

The superb Torrazzo at Cremona in Lombardy, which is 75 feet higher than the better-known Campanile at Venice

fortress as well as a church; this dual conception seems to extend to the huge western tower rising in four receding stages, the uppermost of which is a real Janus, the eastern face square and forbidding, the western semi-octagonal and gracious.

It was at Albi that there arose the strange religious sect known as Albigenses The city suffered grievous damage as the result of the protracted wars that took place before these heretics were at last exterminated by the authorities.

The 15th century was the golden age of tower building, and the most daring and elaborate conceptions, especially in Germany and the Low Countries, date from this century, though they were sometimes completed in the next and even in modern times. It frequently happened that only one tower of a pair was carried up to its full height, and there was in Germany a special fondness for open-work spires. It has been observed that the junction of the spire is often insufficiently marked, in contrast to English design, and the outline of the whole steeple is consequently weak. The western tower of Strasbourg (465 feet), completed in 1439, is a typical example; another of the same date is the south tower of St. Stephen's at Vienna (448 feet).

Though actually dating only from the 19th century, the western towers of Cologne cathedral, 515 feet high from the ground and with foundations descending 65 feet below it, were erected from a 15th-century design; and the same may be said of the soaring spire at Ulm on the Danube, which, with its 528 feet, claims to be the highest church tower in the world. The tower at Malines in Belgium, begun in 1452, was intended to be the highest in Christendom, but a height of only 318 feet out of a projected total of 551 was attained. The north-western tower of Antwerp cathedral (404 feet) was begun in 1352 and completed in 1592 with an elaborate open-work spire, which Charles V compared to Mechlin (Malines) lace. The most famous tower in Belgium is the belfry on the town hall (*Tour des Halles*) at Bruges (1280 to 1480), which rises 260 feet above the main building and is of unusual and somewhat top-heavy design; its carillon of 49 bells beats that of Antwerp by two.

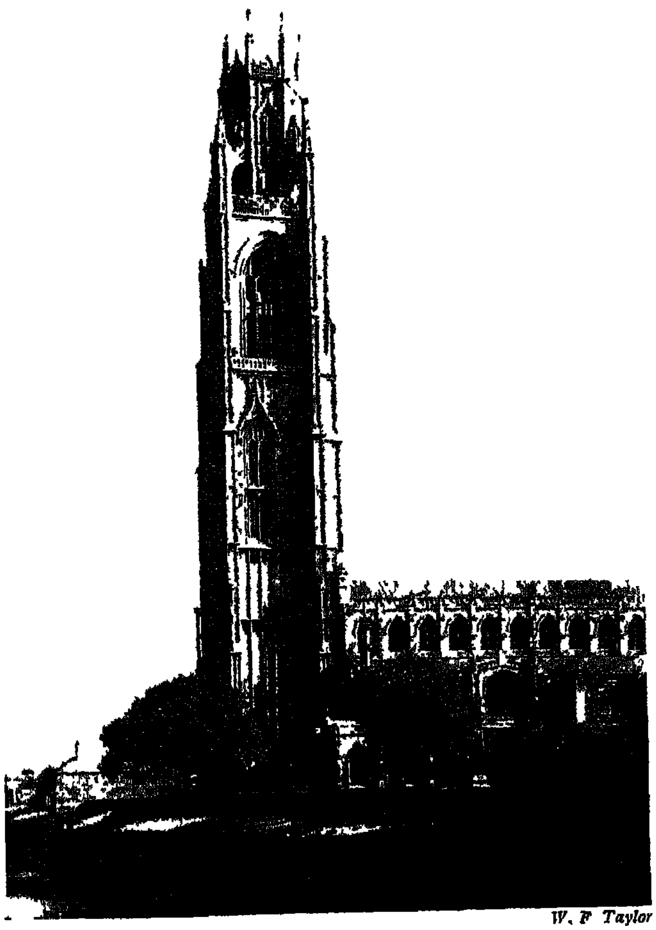
Italian Gothic Bell Towers

The Gothic style in Italy was of short duration; its crowning achievement was Giotto's campanile at Florence (1324), which Ruskin eulogized as the one building in the world that combined all the characteristics of noble architecture; it is 292 feet high, and the two middle stories are "equal but dominant over smaller divisions below and subordinated to the noble third above." At Cremona in the plain of Lombardy there rises the superb but little-known Torrazzo,

a huge square tower surmounted by a graceful octagonal lantern of two stories, 397 feet high in all. This is far loftier and indeed more pleasing than the famous campanile at Venice, the original of which, built in 1329, collapsed in 1902 and, in spite of its 322 feet, did surprisingly little damage to its surroundings. In contrasting Italian and English types Ruskin made a grossly unfair comparison between this tower and a small modern tower in Edinburgh. He should rather have taken a tower like Boston "Stump" (266 feet) as truly typical of English style; "our detestable Perpendicular," as he was pleased to call it, however it may fail in other ways, is most admirably suited for carrying the eye upwards, and whereas the tower at Boston resembles a vigorous sapling shooting up to the light of heaven, the campanile at Venice is far more like an enormous peg driven into the ground—in any case it is quite out of proportion and keeping with the delicate buildings beside it. Furthermore, the English buttresses that found such disfavour with Ruskin have so far prevented collapse.

Loftiest and Queenliest of English Steeples

In England our greater churches are conspicuous for length rather than height and often achieve the culminating glory of a lofty central tower, in several cases with a pair of western towers as well. Lincoln cathedral on its hill has a noble trio of the 14th century; York's three date from the 15th, the massive central tower contrasting with the graceful western pair. The central towers of Canterbury and Gloucester are splendid creations of "our detestable Perpendicular." Spires crown the central towers of Chichester (277 feet), Norwich (313 feet), Salisbury (404 feet), and all three at Lichfield. Since the destruction of the 500-feet lead-covered wooden spire of Old St. Paul's in London, Salisbury spire may claim to be the lo ,est and queenliest steeple in England; in he quaint language of the antiquary Leland, "The Tourre of Stone and the High Pyramis of Stone on it is a noble and a memorable Peace of Work." In our parish churches the tower is most frequently at the west end, like Boston "Stump," and may be seen in its full stature. Much could and indeed has been written about our local styles of tower building. In the old diocese of Lincoln spires were the fashion, and specially fine examples are found at Grantham, 281 feet high and thickly set with crockets; at Louth, 300 feet and constructed in fourteen years for £305 7s. 5d.; and St. Michael's, Coventry, not quite 300 feet and with an octagonal lantern between tower and spire.

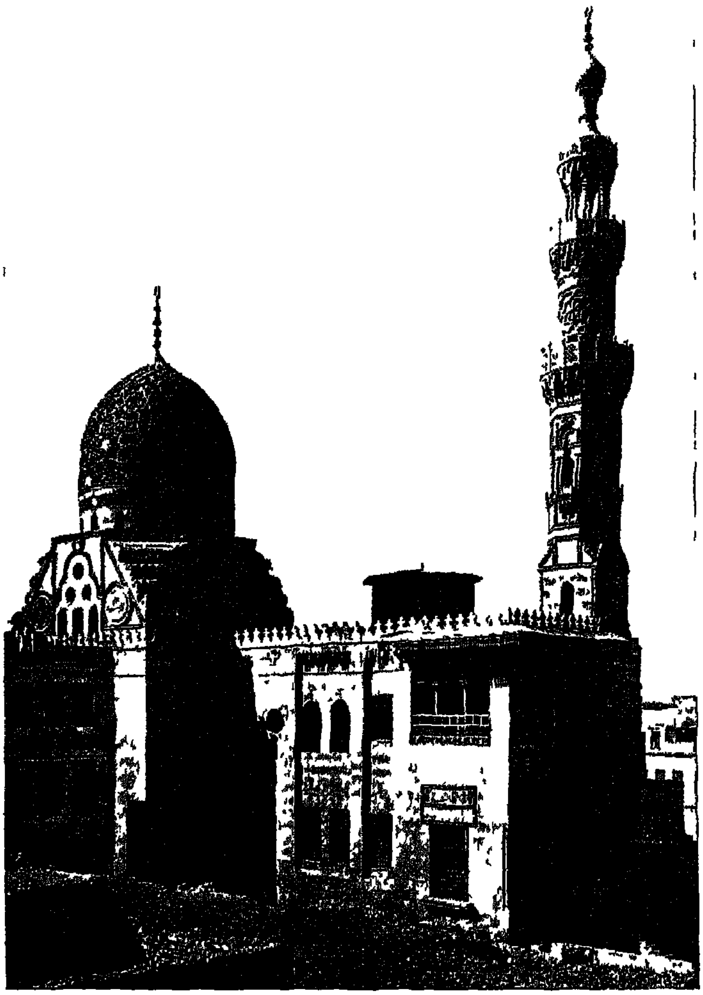


W. F Taylor

Boston "Stump"—a triumph of purely English architecture. Rising to a height of 266 feet, it is a landmark for many miles around

Norfolk and Somerset are both noted for their lofty perpendicular towers. In the former, the tower at Cromer is built of a

beautiful combination of stone and squared flints. A very different material is the granite of Probus church tower in Cornwall, which was not erected till Elizabeth's reign but recalls the small but perfectly proportional Magdalen tower that makes such a noble entrance to Oxford from the east. Still another material is the "new red sandstone" of the central octagon at Nantwich, Cheshire, and the "old red" of the simple but charming steeple at Weobley, Herefordshire. These are but a few local peculiarities; among them we may include what Professor Prior calls "the engineering feat which squeezed out the spire and left it as a mere pinnacle or suspended lantern strutted by four arches, as at St. Nicholas, Newcastle, and commonly in Scotland."



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The highly decorated minaret of the Mosque of Qait Bey at Cairo—a characteristic example of these slender towers of the East

The architects of the Renaissance church towers had no Greek and Roman prototypes to inspire them, but they produced a wonderful variety of designs, some of considerable nobility like Wren's masterly spire (216 feet) at St. Mary-le-Bow. His creation at St. Bride's, Fleet Street, justifies a criticism levelled at Renaissance spires—that they look as if the various tiers could be unscrewed. Attempts to produce novel ideas sometimes resulted in bizarre effects, as in the corkscrew spire of Our Redeemer's church at Copenhagen and the *ridiculously tapering* Ionic column at St. John's, Horselydown in Bermondsey.

Prayer Towers of Islam

So much for the towers of Christendom. Before passing on to the East we must first glance at a magnificent creation of Moorish architecture in Spain, the great Giralda at Seville, erected in 1195, probably as a symbol of power though later turned to the use of a minaret. In plan it is 45 feet square, and its tile-faced walls are nearly 10 feet thick; the original portion rises to a height of 185 feet and is surmounted by a graceful Renaissance lantern (1568) bearing the inscription "Nomen Domini Fortissima Turris" and a thirteen-foot figure of Faith with a banner as a vane. The more usual type of minaret, whence the faithful Mohammedan is called to prayer, is a slender pencil-like structure; specially good examples stand about the mosque of Suleiman the Magnificent (1550) at Istanbul, and a highly ornate specimen adjoins the mosque of Qait Bey at Cairo. In India there is the Kutb Minar at Delhi (1200), which rises to a height of 238 feet, tapering gracefully from a diameter of forty-seven feet to nearly nine. The shaft consists of five stories enclosing a spiral

staircase and was crowned by a now broken cupola which fell during an earthquake in 1803. The original purpose was doubtless a muezzin's tower.

But we have passed over, both in space and time, a truly astonishing monument of Muslim architecture, the Gunbad-i-Qabus, standing outside the ancient city of Gurgan, some fifty miles north-east of Astarabad in Persia. It was a tomb built about the year 1000 for the Amir Qabus of the Ziyarid dynasty in Khurasan, in plan circular within, but ten-sided outside with angular buttresses, in height and circumference nearly 200 feet; there is no sign of stairway or other mode of ascent, and the only light comes from a small window in the conical roof. It is built of fine bricks of a golden buff colour and bears an Arabic inscription in duplicate made of projecting brickwork. It has been called one of the four supreme masterpieces of Persian architecture.

The Quaint Pagoda

A special kind of tower is associated with the Buddhist religion, it is familiarly known as a pagoda and often houses the relics of Buddha or of a saint, though it may be erected in any place as a work of devotion. One of the most famous and typical of Burmese pagodas is the Shwe Dagon near Rangoon, a bell-shaped mass of brickwork, covered with gold-plates and rising in a tapering spire 312 feet from a high platform; at the summit is a metal framework studded with jewels. On the platform are many spire-like objects with tiers of projecting roofs, each slightly smaller than the one below. Tiers of roofs are the great feature of Chinese pagodas, which are usually polygonal and have from three to thirteen stories, sometimes very crowded together. At Soochow there is a nine-storied pagoda of stone and wood, 250 feet high; at Changli, 135 miles north-east of Tientsin, there is an ancient pagoda which has thirteen projections all close together and not markedly tapering. The Flowery Pagoda at Canton, dating from the 6th century A.D., is octagonal, nine-storied, and 270 feet high. But the loveliest must have been the Porcelain Tower at Nanking, destroyed in 1853. Professor Banister Fletcher says of it: "It was an octagon, 40 feet in diameter and 200 feet high. The eaves of the roof to each story curled upwards, and from the angles bells, numbering 150, were hung. It was built of brick, coated with coloured slabs of green glazed porcelain, on which its effect mainly depended."

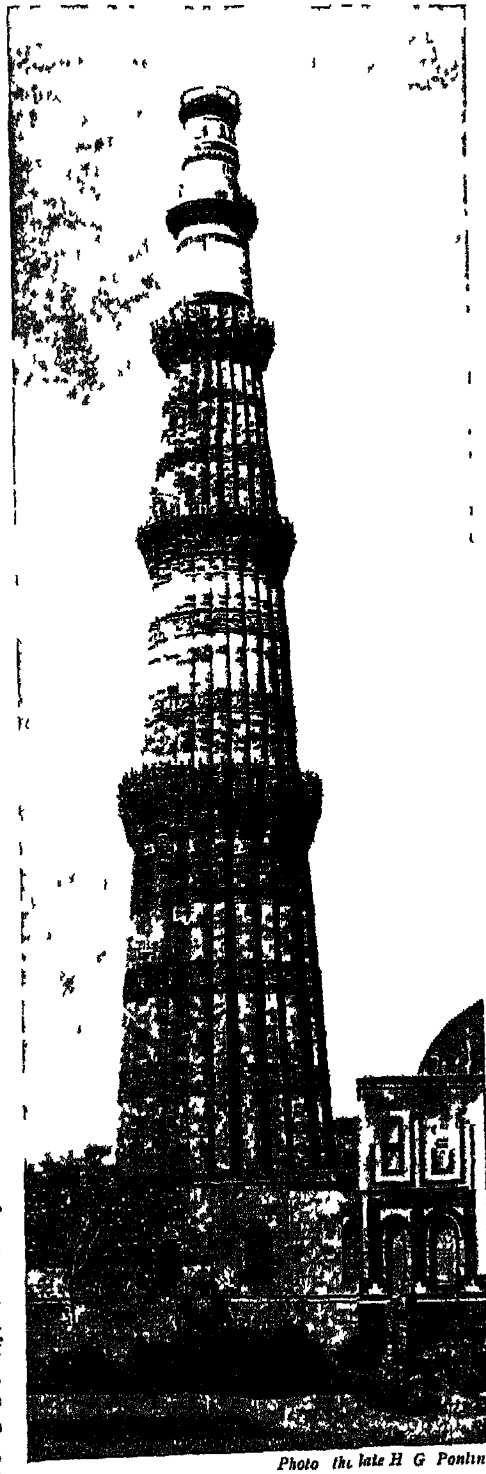


Photo the late H G Ponting

Called the "Glory of Delhi"—the Kutb Minar, begun by Kutb-ud-Din in the 13th century, possibly as a memorial to his victories

Only a few among many notable modern erections can be noticed here. The Gothic revival in the 19th century led to attempts to rival medieval creations. The west tower of St. Nicholas, Hamburg, 485 feet in height, was built in 1874 from the design of Sir Gilbert Scott, whose son designed an imposing central tower for Liverpool cathedral. When the Houses of Parliament at Westminster leaning six feet out of the perpendicular, did not meet with popular approval when it was first erected about 1900; but its long smooth shaft carrying the eye up to the graceful cupola is now a familiar landmark and holds an honoured place among London monuments. One of the most famous of modern towers is Ragnar Ostberg's strikingly original design for the town hall at Stockholm, with

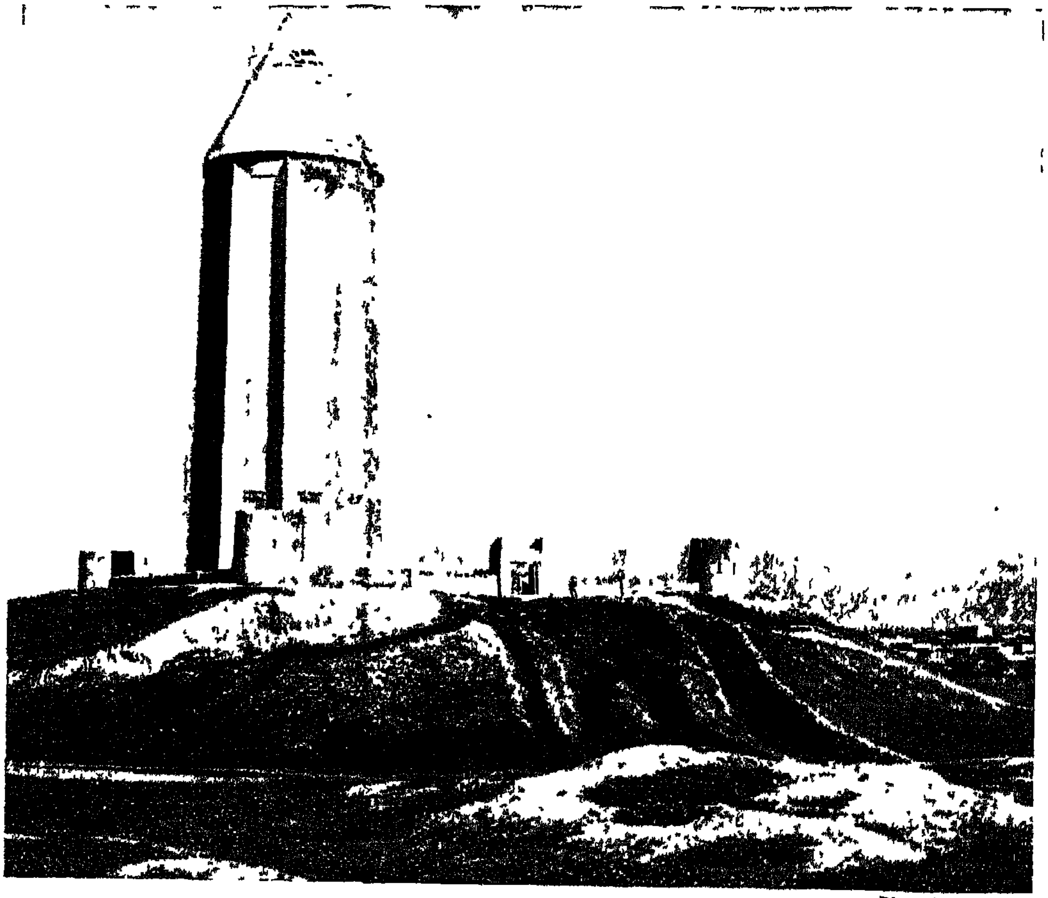
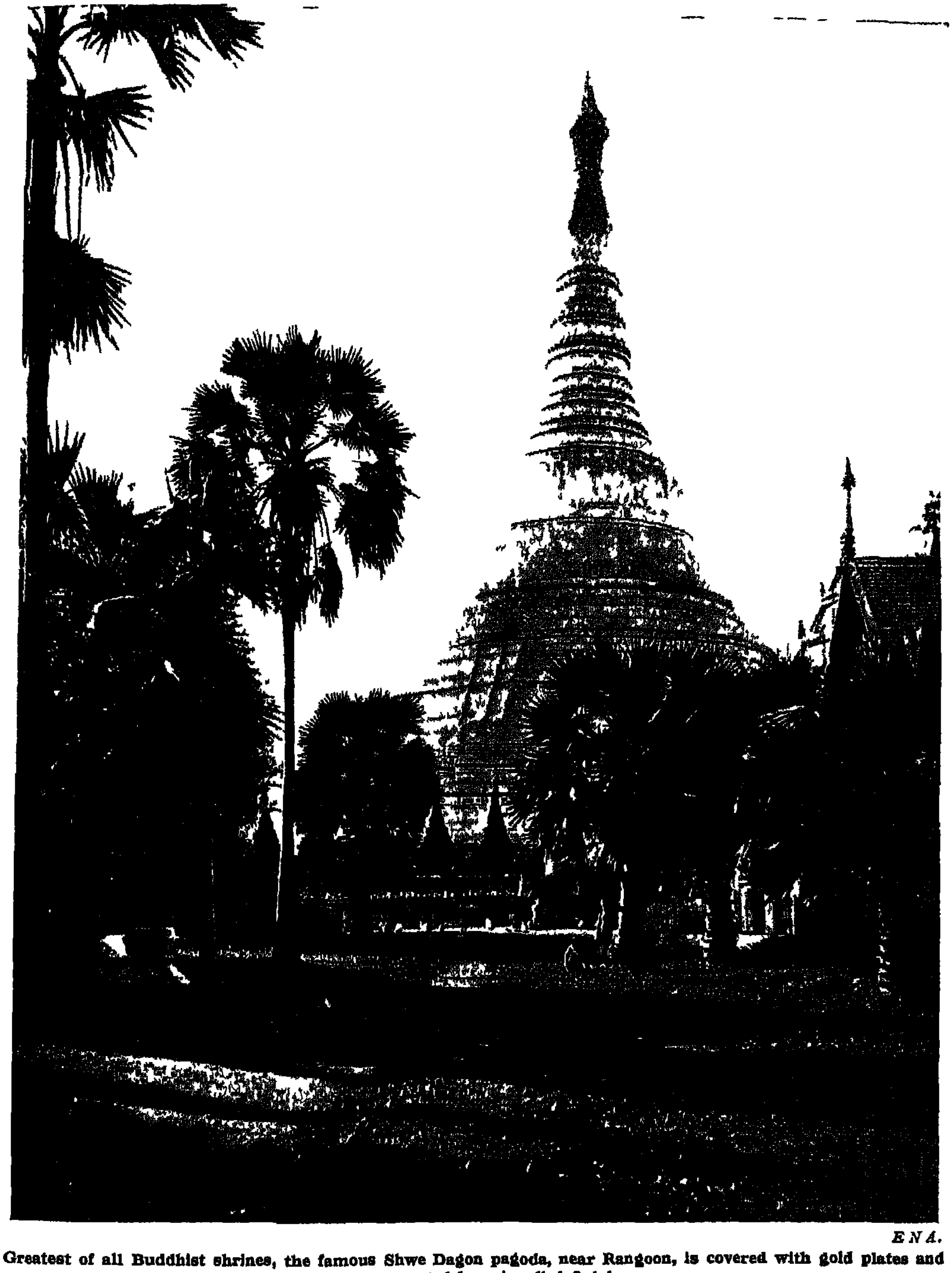


Photo: Robert Byron

A supreme masterpiece of Persian architecture—the wonderful Gunbad-i-Qabus (Dome of Qabus), in N.E. Persia, nearly 200 feet high and built of fine bricks of a golden buff colour

were rebuilt in 1840-50, Sir Charles Barry included two stately towers, the massive Victoria Tower, 336 feet high and 75 feet square, and the slimmer Clock Tower, 320 feet to the finial, both rather overloaded with Gothic ornament. The design of the very pleasing tower at the Imperial Institute, 280 feet high, may have been suggested to the architect, Sir Thomas Collcutt, by the Tour St. Antoine at Loches in France. J. F. Bentley's great campanile at Westminster cathedral, 284 feet high and tapering walls of dark-toned brick and a crowning lantern, somewhat suggestive of a lighthouse.

The famous Eiffel Tower, whose name commemorates its designer, belongs to engineering, rather than to architecture. It was completed in 1889, and rises to the great height of 984 feet, with its four piers sunk thirty to forty-five feet into the ground; we are told that it is constructed of 12,000 pieces of metal fastened by 2,500,000 rivets. In recent years it has been turned

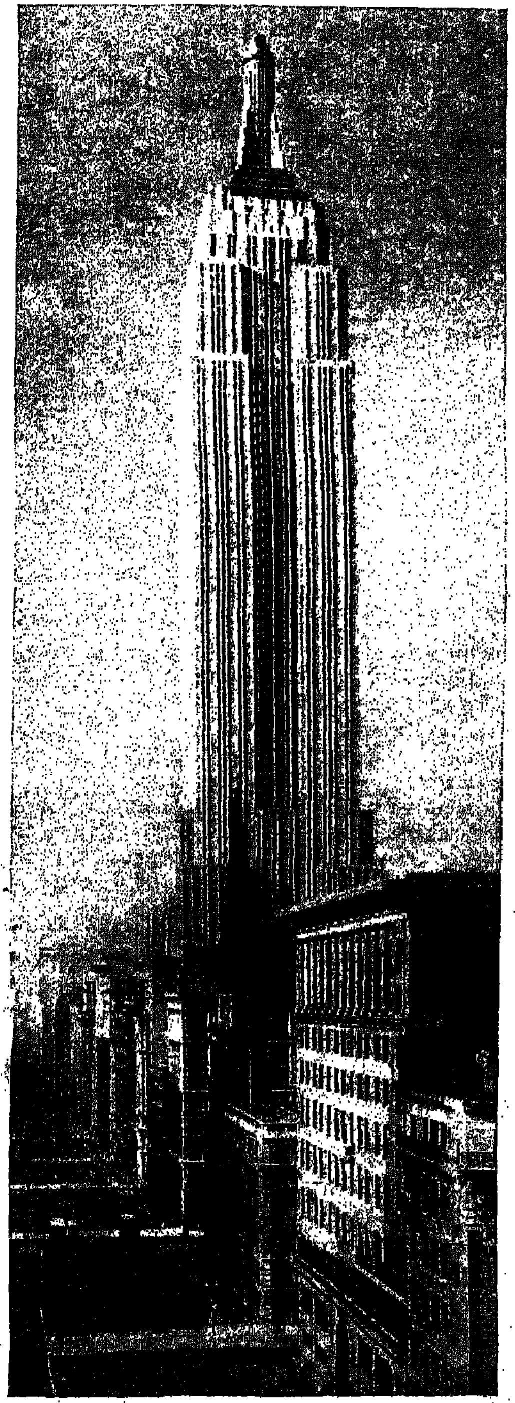


E N A.

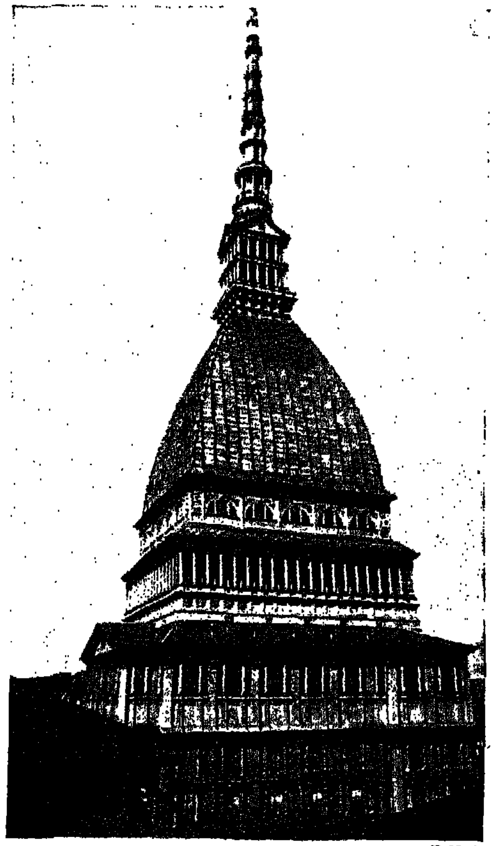
Greatest of all Buddhist shrines, the famous Shwe Dagon pagoda, near Rangoon, is covered with gold plates and surmounted by a jewelled finial

Designed for the Paris Exhibition of 1889, the Eiffel Tower is now one of the most familiar landmarks in the world. Electric lifts run to the top, from which a magnificent view is obtainable. The tower is an important meteorological and wireless station

to practical use, being equipped with a powerful wireless installation. The English attempt to outdo it was a dismal failure; the



Possessing the distinction of being the highest edifice in the world, the Empire State Building, New York, has 102 stories and is 1,250 feet high



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The Mole Antonelliana at Turin was begun in 1863 as a synagogue. Though loftier than the spire at Ulm, it is artistically unsatisfying

tower at Wembley Park was projected to be 1,200 feet high but never rose above the first story and was ultimately scrapped. New York "sky-scrapers" are also in the nature of engineering feats, though the ensemble as seen from the water is certainly effective; these buildings are economically justified by lack of space to spread laterally. Finally we must mention an ungainly erection at Turin, the Mole Antonelliana. This starts as a huge block forty-four yards square and for about one-third of its height consists of receding stories ornamented with many columns; the middle portion is an elongated four-sided dome of enormous size, and this is surmounted by a square block culminating in a tapering spire. Its total height of 536 feet makes it a trifle higher than the spire of Ulm; but in the attainment of this distinction any qualities of elegance or proportion have been sadly sacrificed. In our brief survey of the world's towers we thus end where we began, on a somewhat "vainglorious" note.

CHAPTER XI

THE MAJESTY OF FALLING WATERS

LIKE the mountains, though not perhaps to the same extent, waterfalls have been regarded with awe and terror by uncivilized men. This is not surprising when one sees to-day an immense mass of water tumbling over rocks and precipices with a resounding noise; and it must have been much more terrifying to primitive man, who knew nothing of the law of gravitation. It is said that the Indians who lived near Niagara believed that the Fall was a god and that the noise of the falling water was the voice of the Great Spirit, whose home was in the spray. Every year they offered up to him the fairest maiden of the tribe and a portion of their crops and of the animals they had killed for food.

Everyone knows what a waterfall is, but not everyone is sure of the difference between a waterfall and a rapid. There is no hard and fast rule on this matter, any more than there is in the difference between a mountain and a hill, but it is suggested by one writer on the subject, Mr. E. C. Rashleigh, in his book "Among the Waterfalls of the World," that to be a waterfall the water must make a vertical leap of not less than fifty feet. If it makes leaps less than that it is but a series of rapids; if it makes one small leap it is a cascade or cataract.

How a Waterfall is Measured

Some will doubtless ask another question: How does one measure the greatness of a waterfall? How do we know that Niagara has been beaten by Guayra? The main points to be considered are volume, height and width, but width is the least important of the three. Volume is reckoned in cubic feet per second. According to this, Guayra sends down more than double the volume of water sent down by Niagara, 375,000 cubic feet per second against 158,000, both these being minimum figures. The Victoria Falls, on the other hand, send down far less water than Niagara, but it descends from nearly double the height and on this account Victoria was considered at one time the greatest waterfall in the world. We prefer, however, to reckon by volume, and although this varies enormously in some falls between one part of the year and another—especially when the immense increase due to floods is operating—it is certainly the most satisfactory standard of comparison.

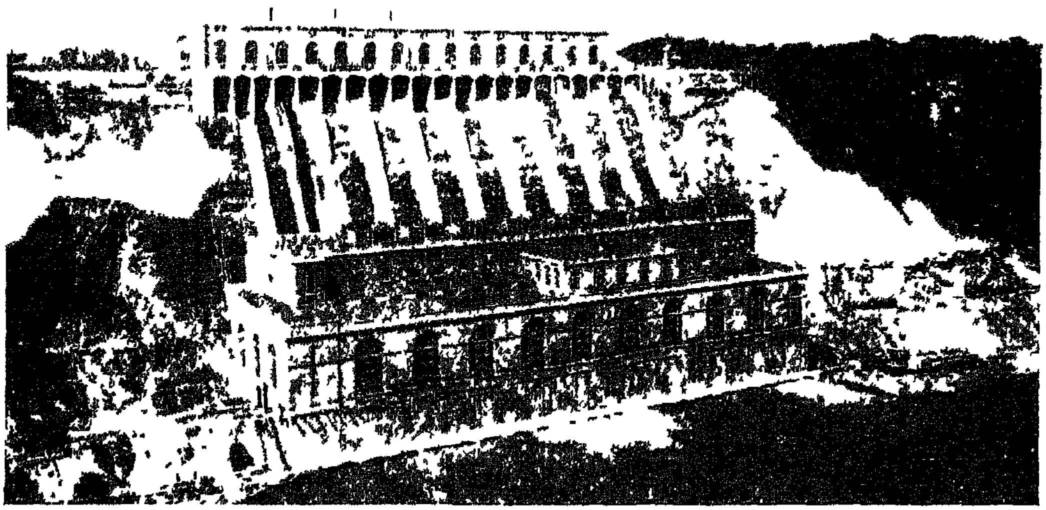
The waterfall is almost everywhere a thing of beauty, for, to the beauty of the water itself, there is added the element of movement in its most majestic form. The attraction that water, and therefore waterfalls, have for the artistic mind and to a lesser extent for all sentient human being has been expressed in a gre beauty by John Ruskin . Painters" writes as follows:

Water—the Wonder Worker

"Of all organic substances, acting in their own proper nature, and without assistance or combination, water is the most wonderful. If we think of it as the source of all the changefulness and beauty which we have seen in the clouds; then as the instrument by which the earth we have contemplated was modelled into symmetry, and its crags chiselled into grace; then as, in the form of snow, it robes the mountains it has made with that transcendent light which we could not have conceived if we had not seen; then as it exists in the foam of the torrent—in the iris which spans it, in the morning mist which rises from it, in the deep crystalline pools which mirror its hanging shore, in the broad lake and glancing river; finally, in that which is to all human minds the best emblem of unscarred, unconquerable power, the wild, various, fantastic, tameless beaut of the sea; what shall we compare mighty, this universal element, for and for beauty? Or how shall we its eternal changefulness of feeling? like trying to paint a soul."

Waterfalls are chiefly found in mounta ous countries, though some of the large for instance Niagara and the Victoria Fa are in flat lands. The reason is that in s regions the great rivers have trib streams whose beds have not been down as yet to the level of the main the water must therefore make a somewhere. In more level areas the waterfall is generally due to the existence of rocks with different powers of resistance to erosion. For instance, the Niagara Falls are due to the resistant layer of limestone that covers less resistant soft shales.

Another type of waterfall is found in limestone districts where the water disappears underground in a channel dissolved by the stream. This is the case with the



Co urtesy of Cana lian National Rl s

The waters of Niagara harnessed to supply electric power—concrete conduits lead the water down the cliff-side to the turbines below, at the great Chippewa Power Gate

turn, and the rotating axle is coupled to enormous dynamos which supply electrical energy.

With the dawn of the new century came new and wonderful uses of electricity. Energy from hitherto wasted water power offered infinitely greater potentialities than the old ide system of hydro-mechanics. The initial , perhaps, was slow, but once the first lectric schemes proved not only but amazingly successful, a wonderful f expansion in this field began. We still scarcely beyond the threshold of era to-day

nt Power in the Rivers

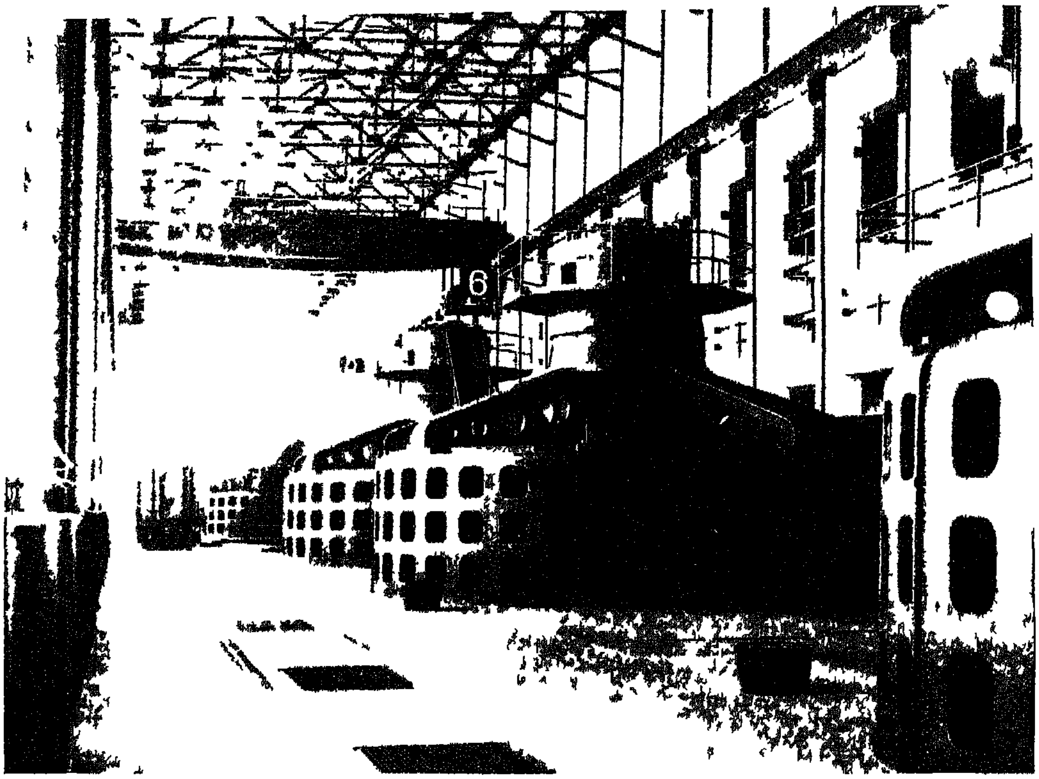
recent estimate of the potential horse- of the world's rivers gave a figure of ,000. Almost half of this available practically undeveloped and flow- waste in the great rivers of Africa. South America has great resources of water-power, only about 1 per cent. of which is so far utilized. The next greatest source of hydro-electric power after Africa is North merica; but here development has been pid and continuous and already something ike one-third of the potential power has been harnessed; a like proportion is also given for Europe.

Many differing estimates have been given regarding the output of hydro-electric power in various countries. The following table is sufficiently accurate for comparative purposes, and will serve to give a mental picture of the position to-day. Assuming the world output (1934) to be about 39,000,000 kilowatts, the following table shows the principal producers:—

Country	*Kw.*	*Per cent.*
U.S.A.	11,800,000	30 06
Canada	5,256,000	13·39
Italy	4,348,000	11·08
Japan	3,150,000	8·03
France	2,780,000	7·08
Germany	2,300,000	5·86
Switzerland	1,900,000	4 84
Norway	1,800,000	4·71
Sweden	1,400,000	3.57
Spain	875,000	2·23
U.S.S.R.	758,000	1·93
Austria	725,000	1·85
Brazil	525,000	1 34
Finland	300,000	·76
India	300,000	·76
Mexico	235,000	·60
Great Britain	228,000	·58
New Zealand	225,000	·57
Jugo-Slavia	190,000	48
Czecho-Slovakia	110,000	·28
		100·00

Of the world's great hydro-electric schemes that utilizing the Niagara Falls is probably the best known mainly because at the time of its inception it was the most ambitious scheme yet undertaken Fed by Lake Superior the largest fresh water lake in the world the conformation of the falls and their approaches made the task an easy one for modern engineers

The general principle governing the construction of all hydro electric plants is the same Where a fall of water occurs, the



Courtesy of Canadian National Rlys

Canada has not been slow to develop her natural resources for the production of electricity Huge turbo-generators of the Saguenay River Power and Development Co at Lake St John, Quebec

river is diverted some distance above the fall into what is known as the "head race" All debris which might smash the rotating turbine is barred, and the water rushes along the penstocks and through the turbines situated beside the foot of the falls, whence it escapes in the "tail-race" to rejoin the parent river on its journey to the sea

The falls at Niagara, with a total drop of 310 feet to the whirlpool below, have a potential capacity of 6,000,000 horse-power for the full river flow On the American side, the power production is in the hands of a single huge concern that has a total development of 560 000 horse power three of its gigantic units being rated at 70,000 horse-power each On the Canadian side, three operating companies take energy from the falls to the extent of 680,000 kw The water is diverted into a canal twelve and three quarter miles long whence it passes to a screen-house where the water is filtered and all debris removed From there the mighty stream is conveyed in gigantic pipes 14 feet to 16 feet in diameter Three phase alternating current is generated at 12,000 volts, and is transformed up to 110,000 volts for transmission

Although the U S A has a larger hydro electric output and many more plants, Canada with a potential power development under this system of almost 8,000,000 horse-power has a far greater electrical output per head of population The great bulk of this power is developed in Quebec province, where pulp mills are run, and in the western districts of the Rockies, where the Columbia and other turbulent rivers provide power for saw-mills and factories

On the Saguenay River in Quebec Province

a luxury. On the Lower Glommen River are four notable hydro-electric plants with a total capacity of 300,000 kw., of which more than half is already developed. Over 1,000,000 horse-power, derived from the energy of falling water, is used annually in Norway. Although the price has recently been raised, the present rate of one-tenth of a penny per unit can scarcely be called exorbitant.

Sweden has attempted to develop her water-power much as Norway has done, but the former country is handicapped by colder conditions since it is not open to the warming influence of the Atlantic. In spite of this, almost every waterfall of any size is harnessed to provide electricity to the surrounding area. Stockholm, the capital of Sweden, is supplied with electricity from the Trolhatten Falls, which derive their water-flow from Lake Vener, a sheet of water ninety miles long and forty-five miles wide.

Finland possesses many small lakes, and rapids are a feature of its small rivers, most of which are capable of profitably providing electric-power. But the scattered population outside the big towns renders it inutile to greatly exceed the present figure of 300,000 horse-power. Two-thirds of this output is derived from the double fall at Saima Lake.

Switzerland, Germany and Italy have been fully alive to the value of their water-power, and the electrification of many of their railway systems has followed from hydro-electric development. Switzerland possesses, at Lac Fully, the highest working head of water in the world. The plant is situated at a height of 5,400 feet, and the pressure of water in the pipe-line near the power-house is 2,260 lb. per square inch. In Italy, since the Great War, hydro-electric developments have been spectacular. The enormous plant at Piedimulera, in northern Italy, links up with Swiss electrification schemes.

Germany has a system whereby electric stations which derive energy from coal join up with hydro-electric stations, so that the power "rings" are complete. In France the recently erected power station at Chancy-Pougny on the Rhône supplies electricity to an enormous district, and is one of the most important in the country.

One of the huge 20-ft. conduits that carry the water down 100 feet from the head-race to the power-house of the Shannon hydro-electric scheme

When several years ago *Southern Ireland* became a separate state, the Free State leaders realized the necessity of providing cheap electric power to make fuller industrial development possible. The obvious choice was the utilization of the energy of the Shannon, fed by a chain of lakes that runs through the heart of Southern Ireland. In 1925 the great Shannon hydro-electric scheme was launched, and four years later it was completed at a cost of £8,000,000.

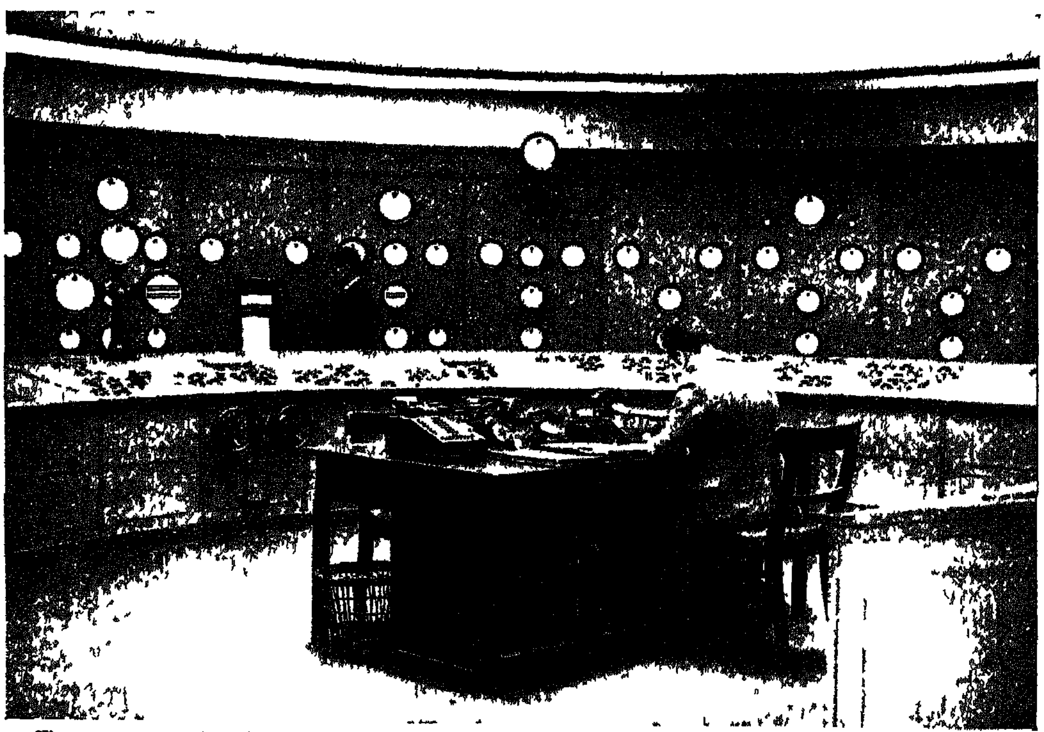
The power-station at Ardnacrusha is situated at the end of a 7½ mile head-race which, taking water from a weir just above Limerick, returns it to the river at the village of Parteen. The station is equipped with three vertical turbines of 38,600 horse-power each, operating at a speed of 150 revolutions per minute. Should necessity arise, the output of the station can be doubled. The current generated at Ardnacrusha is transmitted across country to Dublin by a 110 kw. double line, while another cable conveys power to the city of Cork.

Vast Power Schemes of Russia

Not only cities are thus served, but more than 200 urban and rural areas have been brought into the distribution scheme. Other plans are on foot for further power-plants in the Irish Free State, and before long it is likely that the River Liffey will be similarly harnessed.

Soviet Russia has great supplies of water-power capable of development and this available energy is estimated at 200 million horse-power. One of the most remarkable enterprises was that for using the water-power of the Volga. Begun in 1922, when Russia was still staggering from the effects of revolution and civil war, there was practically nothing in the country ready for such a huge constructive effort as a dam across the Volga. Iron foundries were lacking; bricks were scarce, even nails and screws had to be gathered by collectors scouring the country for material. Yet, in the end, the miracle was performed and Volkhovstroy power-station with eight 10,000 horse-power turbines came into being. In the first four years of its existence the station saved the state 25 million roubles' worth of coal: and, what was more important, the cost of power was reduced by one-half.

The Ukraine has been selected as one of the most important areas of electrical development in the U.S.S.R. Many of the existing stations have been considerably extended, while the new constructions include the largest hydro-electric station in the



The nerve-centre of the Shannon hydro-electric scheme—inside the well-designed and purposeful control-room

world. The rapids in the Dnieper, where the station was erected, have always been an insurmountable obstacle to the utilization of the river, which flows through a densely populated and economically important area. This obstacle, which prevented the establishment of communication between the Baltic and Black Sea regions, is now utilized for the development of the country. The dam erected at the foot of the rapids not only provides power but makes the Dnieper navigable along its entire course.

The Dnieper station, which was opened in October 1932, is equipped with nine turbo-generators each of 62,000 kilowatts capacity and two of 3,000 kilowatts each. The enterprise was begun in November 1927, and since that time, in addition to the hydro-electric station itself, a number of metallurgical and chemical works have come into being and a new town has sprung up. Current is supplied to all these works and also to the neighbouring towns of Dnepropetrovsk and Zaporozhyze.

Before the erection of the station and works it was necessary to transfer peasants from a site of about 100,000 acres to other parts of the country. The dam, which is a mile and a quarter long, used up 43,200,000 cubic feet of concrete. It has raised the level of the upper part of the Dnieper by about 130 feet, making navigation possible along the entire river. The barrage has forty-eight openings closed by water-gates, each weighing about forty-eight tons, which regulate the inflow of water to the turbines.

On the left bank of the Dnieper locks have been built enabling ships to pass from one water level to another. Across the dam, at a height of 172 metres, a wide road has been built for motor-car and tramway traffic; it leads to new industrial districts on the left bank of the river.

WATER TO DRINK

In the early days of civilization the first townships grew up where there was a good natural water supply. But as the population of these towns increased, the supply in the immediate neighbourhood almost invariably proved inadequate and the water had to be brought to cities from sources many miles away, by means of aqueducts. The greatest builders of aqueducts in ancient times were the Romans, and their gigantic schemes for bringing water to their cities are even to-day considered triumphs of engineering. Something has been said about the Roman aqueducts in Chapter XXXVI.

Until little more than a century ago the methods of supply and distribution of drinking water to most towns and cities were usually haphazard and altogether unhygienic. The story of London's water supply illustrates the transformation that has been brought about and the manner of its accomplishment.

The Trade of Water-carrier

Until the 13th century, Londoners relied not only on the "fair wells and springs which they had in every street and lane in the City," but also on the Thames water itself, which either the users or, if they were wealthy, their servants fetched from the riverside. Later the trade of "water-carrier" sprang up, the men following this vocation usually being called "Cobs" since they mostly lived in Cob's Court, a lane leading to the river at Blackfriars. Even at the beginning of last century water for domestic use was drawn from the Thames as far down as London Bridge, and was delivered to consumers without filtration of any kind.

In 1236, the City Corporation commenced the building of conduit houses where public cisterns held the water conveyed there from several fountains and wells in the neighbourhood. Sometimes wealthy persons obtained permission to take a private supply by pipe or "quill" from these conduits direct into their houses. Water for domestic purposes could, in the 14th century, be obtained from these conduits without payment.

For more than three centuries the city authorities continued this wretched supply, the conduit houses becoming more and more neglected. In 1603 plague broke out, when the infected city water is said to have caused over one thousand deaths during a single week, and a total mortality of 33,000. London was aroused to the need of a better water supply, and in 1616 an Act of Parliament empowered the bringing of water from Hertfordshire to the city in a closed trench. This was considered too great an undertaking for the city authorities and it was carried out by private enterprise. The New River Scheme, as it was called, was brought to a successful conclusion by Sir Hugh Myddelton, a wealthy goldsmith and shipping merchant, the work taking 600 men some five and a half years to complete. It is interesting to note that this scheme still supplies part of London's water needs. The New River water supply was brought to the Round Pond at Clerkenwell and conveyed to the City by means of hollow elm pipes. These

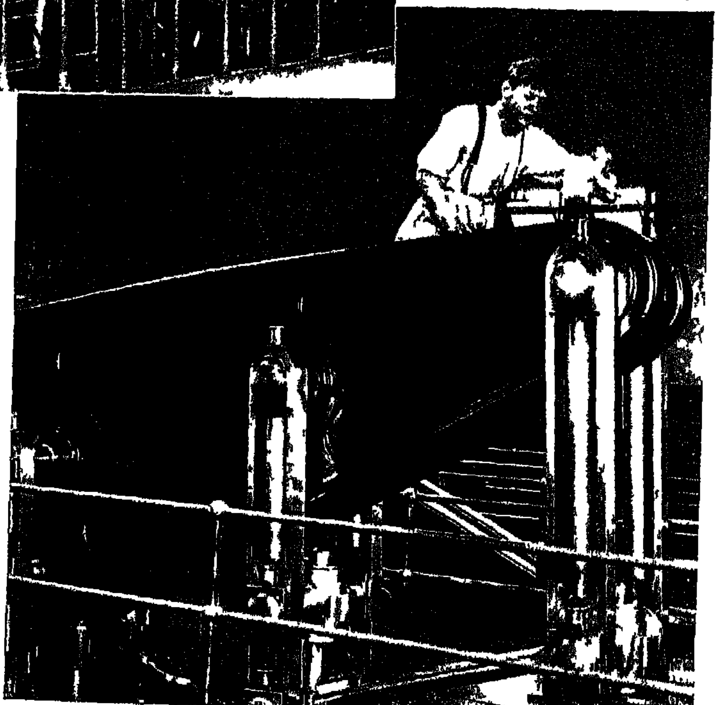
wooden pipes were very unsatisfactory and, the bore being small, it was not unusual for as many as six of them to be placed side by side.

London's water on its way to the tap. A giant flywheel, and pump arm, (*right*), at the Metropolitan Water Board's pumping station at Green Lanes

The establishment of this, the first of London's private water companies, was followed during the next two centuries by the creation of a further seven concerns. The rivalry between these, each with its own systems of reservoirs and mains, was so fierce that often two or three companies touted for customers in the same street. The outcome was that the streets were constantly being dug up, the rival gangs of navvies often engaging in free fights with pick and shovel. In course of time affairs were put on a more sensible basis and the companies each came to have their own particular territory; in 1902 the eight private water concerns then existing were taken over by the public authority, and the Metropolitan Water Board was created.

This Board is the largest undertaking of its kind in the world, supplying as it does 7,500,000 people distributed over an area exceeding 537 square miles. The average amount of water used daily for the past few years has been 279 million gallons, or $38\frac{1}{2}$ gallons per consumer.

Over two-thirds of the Board's supply comes from the Thames, and one-sixth from the River Lee, whilst the remaining sixth is supplied by wells and springs. The present reservoirs have a storage capacity of some 20,000,000,000 gallons; three additional reservoirs are to be constructed, and these will increase the storage capacity by a further 11,600,000,000 gallons. The largest of the present storages is the "Queen Mary"



reservoir at Littleton, near Staines. When full it contains 6,750,000,000 gallons of water, a quantity sufficient to supply London only for twenty-three days. The area of the reservoir is 723 acres and the depth of water

is thirty-eight feet. Including the nearby pumping-station. it cost £2,000,000 to construct The water is drawn from the Thames through specially constructed intakes which are equipped with meters Almost all the Board's reservoirs are filled by means of pumping operations. The water is then double-filtered by being passed slowly downwards through a thick layer of fine sand, and is later treated with minute

Water is delivered to consumers through a network of cast-iron mains which total 7,800 miles in length and which vary in diameter from forty-eight to three inches. To mains of from three to six inches in diameter are connected the smaller lead pipes (usually half-inch in internal diameter) which carry water into dwelling houses.

London's water supply requires no fewer than 4,450 men to keep up its constant and

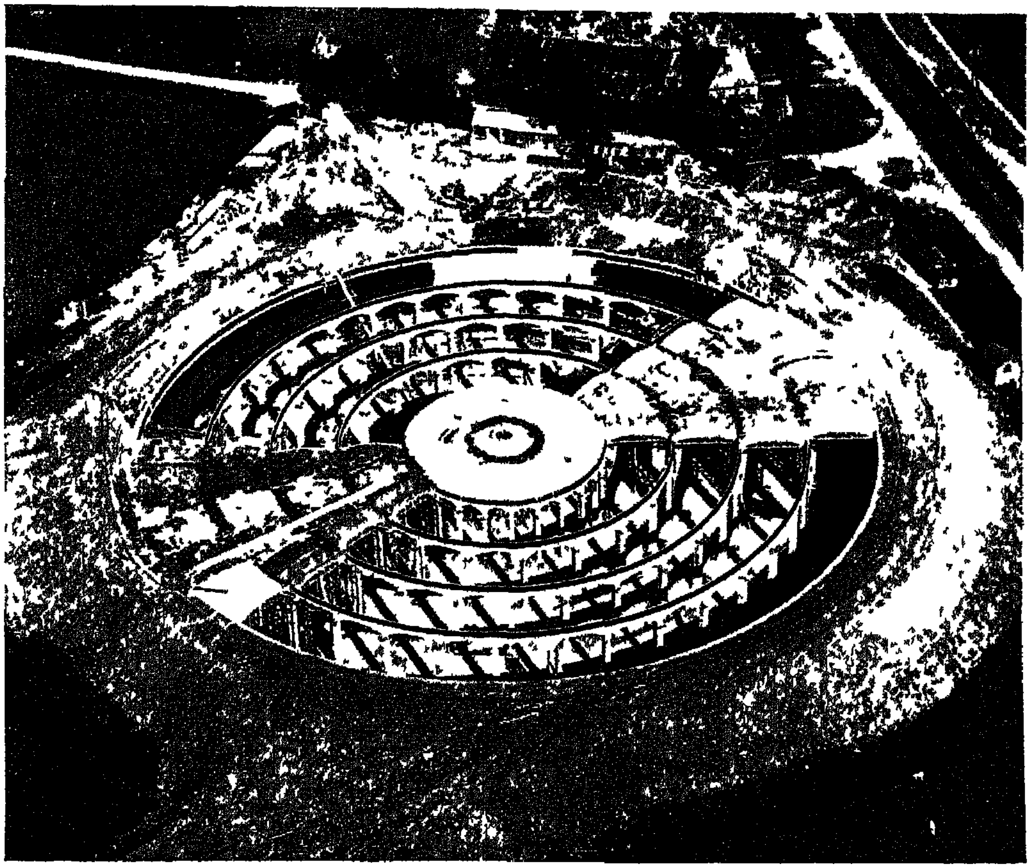


Photo Aerofilms, Ltd.

Rather like an enormous wasps' nest—a striking air view of the Meriden Reservoir, Coventry, during construction. It holds 10,000,000 gallons of water in store for the City's use. *See also illustration page* 180

quantities of ammonia and chlorine in order to deal with any bacteria still remaining.

The plant in the many pumping-stations owned by the Board is required (1) to pump river water into storage reservoirs, (2) to pump filtered water into supply, and (3) to raise water from wells and pump it into supply. The "Queen Mary" reservoir, for example, is filled by four centrifugal pumps driven by single-cylinder uniflow steam engines, each pump being capable of raising 75,000,000 gallons per day to a height of forty feet.

unfailing service. Their work, mostly unseen by London's millions, ensures a supply of pure and wholesome water available at every tap in the metropolis at an average cost of 2½d. a ton.

Some of our towns have to go far afield for their water supply, and even then do not find a ready-made source that will give them the abundance they require. Narrow valleys have to be dammed and artificial lakes created which may serve as reservoirs. A thousand-acre lake was created in this

manner across the valley of the River Vyrnwy, a tributary of the Severn, in order to supply water to Liverpool, sixty-eight miles away. The making of the aqueduct in connection with this scheme is described in Chapter XIV. Birmingham similarly draws water from reservoirs in the Welsh mountains, seventy-three miles distant. Manchester is served by lakes in the Lake District—notably Thirlmere—through a pipe-line ninety-six miles in length.

Normally containing part of Coventry's water supply—the weird interior of the Meriden Reservoir. *See also illustration page 179*

In contrast to the modernity of most great water supply schemes is that of the port of Aden, the British possession at the mouth of the Red Sea. Here, gigantic stone storage tanks which date back to the days of Solomon are still used and serve a town which often knows no rain the year through.

The story of the first adequate municipal water supply for the French port of Marseilles reads like a romance. Up to the 18th century the meagre supply was polluted and often led to terrible outbreaks of plague. After a particularly bad outbreak, a poor youth named Guyon determined to remedy this state of affairs. Collecting horse-shoe nails and dealing in rags and rubbish, he laid the foundations of an immense fortune, in the process of amassing which he became the best-hated miser in the town. To everyone's surprise, at his death he bequeathed his fortune—which he had hoarded solely to this end—for the construction of a great water-supply scheme.

Between Mundaring and Kalgoorlie, in Western Australia, has been laid a great aqueduct that bears comparison with those of the western world. The pipe-line is 351 miles long and, traversing country which is almost desert, contains a month's supply of water for the goldfield town. A series of pumping-stations is arranged along the run of the pipe-line, at intervals of a score or so miles.

But soon the Mundaring-Kalgoorlie aqueduct will rank second to a gigantic scheme now in course of construction across the deserts and mountains of Southern California. Although the actual channel will be 110 miles shorter than its Australian rival, it will supply thirteen great cities through 144 miles of distribution mains with the colossal daily flow of a million million gallons of water. The source of supply is the Colorado River, and the intake will be from an enormous reservoir created by the Parker Dam, 150 miles below Boulder Dam. From here, the aqueduct will traverse desert and mountains, piercing the latter by twenty-nine tunnels, each sixteen feet in diameter, and having a total length of ninety-one miles.

The two longest tunnels—the East Coachella of eighteen miles and the San Jacinto of thirteen miles—would have taken years too long by the ordinary method of boring from both ends simultaneously. The

engineers therefore decided to bore not only from both ends but from the top and sides as well, so that at the moment the tunnelling is going on simultaneously from eight different points. At five places along the projected pipe-line, elaborate pumping machinery is being installed. For the first 130 miles the water will be raised 1,537 feet by means of these pumps, and at the fifth station it will be forced up 440 feet almost vertically. Two years were spent in surveying before work could be started; then came the making of hundreds of miles of road to link up the thirty-one construction camps, where 4,400 men are at present labouring on the scheme. The ninety-one miles of tunnel are being excavated at the rate of three and a half miles per month, and the world's greatest aqueduct is expected to be completed within six years.

CHAPTER XIII

WONDER AND BEAUTY OF THE EARTH'S CAVERNS

MORE than the mountain and the waterfall the cave is and has been a place of awe and terror; less a thing of beauty and delight. But this does not prevent some of the caves from being truly regarded as wonders of the world—marvels created by one or other of the strange and fearful processes that have built up the universe of to-day.

According to their method of formation caves can be divided into several groups. One consists of the sea cave, seen so often on rocky coasts; they have been produced by the action of the waves, which have gradually forced a hole in the cliff by dashing sand or gravel against it. This is most easily done when lines of fracture and fissures exist in the rocks.

Natural Cave-forming Agents

The air plays an important part in this process. The pressure of the oncoming water drives this into every crevice of the rock and when the waves fall back it suddenly expands and dislodges fragments, thus enlarging the aperture. This accounts for the fact that caves of the kind often extend far beyond the limits reached by the waves, and may even turn upwards and reach the surface of the land some little way inland. The openings which are formed in those cases are the blow holes that are so frequently seen on rocky shores.

But more caves, including the most famous of all, have been produced in another way. The water of streams and underground rivers has dissolved the rock around them and so formed caverns and grottoes. This is especially the case in limestone areas. Sometimes rivers will flow entirely underground through a succession of caverns, often adorned with magnificent and beautiful stalactites and stalagmites.

Lava caves are due to the escape of the central part of a lava flow at a period when the surface had coalesced to form a hard crust, leaving the interior still liquid. Earth caves are found in inland cliffs where there are alternate hard and soft beds of rock; the softer layers are eaten away by the action of frost and rain, leaving the harder ones untouched around them.

Many caves have been improved by men, numbers of whom made their homes therein in the early stages of civilization. From the practice of enlarging and improving caves, it is not a far cry to that of making them, especially when the earth formations are suitable. There are examples of artificial caves at Elephanta, in India, in Asia Minor, and in North Africa. In parts of France, Spain and Hungary we can still see dwellings of which all except the front is a cave. Some of these were caves before they were utilized as houses, but others have been dug out for the purpose. Arthur Young in his "Travels in France" describes some caves he saw near Tours: "Where the chalk hills advance perpendicularly towards the river they present a most singular spectacle of uncommon habitations, for a great number of houses are cut out of the white rock, fronted with masonry, and holes cut for chimneys, so that you sometimes know not where the house is from which you see the smoke issuing."

Caves as Dwelling-places

The use of caves as homes and places of refuge, for which they are particularly well suited, goes back to very early times and has found a place in legend and mythology as well as in history. Homer relates how, on his long voyage homeward, Ulysses and his companions sought refuge in the cave on the Sicilian shore where the one-eyed giant Polyphemus lived; and how the sur-

vivors, after he had made his meal off several of their colleagues, escaped owing to the cunning of the wily Ulysses.

Many of the characters in the fairy stories of all lands lived in caves and some of these were regarded as the abodes of evil spirits. The early Romans believed that the sibyls and the nymphs dwelt in caves, and some of the latter were made into temples for the worship of the gods. Temples of this kind still exist in India. Probably the greatest of these is the Buddhist cave temple at Karli in the south of the country. Aladdin was sent by the magician into a treasure cave; the Seven Sleepers of Ephesus slumbered in a cave, and it was in caves that the great medieval emperor, Frederick I, and the Spanish hero Boabdil were supposed to be sleeping until the time came when they would awake to deliver their lands from tyrants. Boabdil was believed to be in a cave in Granada and Frederick Barbarossa in one on the Kyffhäuser Mountain in Thuringia.

Of the use of caves as refuges and burial places there are also many examples. In England there are caves bearing the name of Robin Hood, and King David took refuge from his enemies in the cave of Adullam. Cæsar relates how, during his war in Gaul, the Aquitani fled from him and took shelter in the caves of Auvergne; in Africa, David Livingstone found whole tribes living in caves with their cattle and other belongings. Abraham was buried in the cave of Machpelah, and the catacombs of Rome were used as cemeteries.

Caves have been much employed by smugglers, and dark and romantic stories are told of many of those around the coasts of the British Isles, as well as in other countries.

Treasure Houses of Anthropological Lore

The careful examination of caves during the past century or so has brought to light an immense amount of information about the life and habits of early man, and has proved beyond any doubt that vast numbers made their home in caves. In fact, it is probable that for thousands of years the cave-men formed a very large proportion of the population of the world. The remains found in caves, carefully examined by scholars, yield evidence, too, of what primitive man ate and drank; what were his weapons, his companions, his ornaments and his burial customs. Not only so, but the caves have given much information about life on the earth before the arrival of Man—about the order in which the various animals appeared, and much other matter for the naturalist and the geologist as well as for the anthropologist. Three examples may be given.

In 1810 the cave of Gailenreuth in Franconia, now part of Bavaria, was explored. The bones of the animals which it contained were examined by the great French naturalist, Cuvier, and some of the skulls were found to have belonged to the grizzly bear. These were associated with the bones of the reindeer, lion, wolf, fox, stag, hyena, horse and bison, as well as with those of the great cave-bear. The discoveries were particularly valuable because they proved that the animals whose bones were found had in ancient times lived in Germany.

In 1820 the naturalist, Frank T. Buckland, explored a cave at Kirkdale in Yorkshire. The finds there proved that it had been the home of hyenas, as evidently the broken and gnawed bones of the mammoth, rhinoceros, stag, bison and horse that were found there were from carcasses whose fragments had been dragged in by the hyenas to serve for food. Buckland stated that all these animals had lived in Yorkshire, for it was impossible for the carcasses of the rhinoceros and mammoth to have floated there from tropical regions.

Discoveries in Kent's Hole, Torquay

Somewhat later Kent's Hole, near Torquay, was explored with more important results. There flint implements of a very early type were discovered in intimate association with the bones of extinct animals, thus showing that man lived in England at the same time as these animals. Three distinct periods of human life are represented in this cave. In the lowest layer the remains of bears and flint implements of a rude type were found. Above this is a layer of red earth that contained bones of the hyena, mammoth, lion, rhinoceros and other animals, in association with flint implements and an engraved antler. In the top layer of earth were articles that proved the cave was in use during the neolithic, bronze and iron ages; some of these finds are pieces of Roman pottery.

The earliest decorative art is found in caves. There are persons living who can remember the interest that was aroused when a Spaniard, quite by accident, discovered some wall paintings in a cave at Altamira. Regarded as the earliest wall paintings in the world, these evidently depict hunting scenes. Similar paintings have been found in caves in France, where bisons, reindeer, mammoths, bears and even horses are represented. The outlines were drawn

first and colour was afterwards filled in; brown and red ochre and black oxide of manganese were used for the purpose.

Engraving, another form of art, was practised by these primitive men. In some of the French caves figures engraved on antlers have been found. These have been described by the foremost authority on caves and cave-men, Sir W. Boyd Dawkins, who, after mentioning the contents of the refuse heaps, says: "The most remarkable remains left behind in these refuse heaps are the sculptured reindeer antlers and figures engraved on fragments of schist and on ivory. A well-defined outline of an ox stands out boldly from one piece of antler; a second represents a reindeer kneeling down in an easy attitude with his head thrown up in the air so that the antlers rest on the shoulders and the back forms an even surface for a handle, which is too small to be grasped by an ordinary European hand; in a third a man stands close to a horse's head, and on the other side of the same cylinder are two heads of bisons drawn with sufficient clearness to ensure recognition by anyone who has ever seen that animal. On a fourth the natural curvature of one of the tines or prongs has been taken advantage of by the artist to engrave the head and the characteristic re-curved horns of the ibex; and on a fifth horses are represented with large heads upright, dishevelled manes and shaggy, ungroomed tails.

"The most striking figure is that of a mammoth engraved on a fragment of its own tusk; the special curvature of the tusks and the long mane, which are not now to be found in any living elephant, prove that the original was familiar to the eye of the artist. These drawings probably employed the idle hours of the hunter and hand down to us scenes which he witnessed in the chase."

Before describing some of the caves we may give Sir W. Boyd Dawkins's summary of the cave-men living in Europe. "They lived by hunting and fishing, they were fire users and lit up the darkness of the caves with stone lamps filled with fat. They were clad in skins sewn together with sinews of reindeer, or strips of intestines."

Of the thousands of caves that exist all over the world, only a few can possibly be mentioned here, but there is one, the Mammoth Cave of Kentucky in the United States, that no account can omit. This is 85 miles from Louisville, and steamers go to it along the Green River which passes

near its mouth. It was discovered before 1800. The cave is in reality a complicated series of more than 200 divisions, called rooms, domes, pits, galleries, grottoes or avenues. In some of the lower ones there are rivers, lakes and cataracts.

It is entered through a natural arch with a span of seventy feet and from a ledge above it a cascade falls for fifty-five feet to the rocks below and then disappears. The main cave contains several rooms, known as the Rotunda, the Star Chamber, the

[redacted]

pits with some fine stalagmites and stalactites and some very beautiful decorations on the walls. Hovey's Domes are at the end of the cave farthest from its entrance in one direction; in another direction the end is marked by an awesome pit that has been called the Maelstrom.

At one time visitors could go no farther than the Bottomless Pit, as it is called, and even thus far there was a certain amount of danger. But later a wooden bridge was placed across the chasm and

crystals, in which the cave is very rich indeed. Stalagmites and stalactites abound in the Gothic Avenue, which, with Gorin's Dome and the Mammoth Dome, is a feature of the cave, but there are many other rooms in this respect, only a little less notable.

Of these passages Cleveland Avenue is two miles long, and Stileman's—which is in places 200 feet wide—is only a little shorter. Hovey's Cathedral Domes, discovered only in 1907, are five domes each about sixty feet in diameter opening into each other by tall gateways. In 1908 another part of the cave was discovered. This was called the Violet City, and in it are eleven enormous

and autumn, and a voyage along them is a marvellous experience. The first approach is called the Dead Sea, around which are high cliffs. There a pathway has been made and a staircase leads down to the banks of the river Styx, a body of water forty feet long crossed by a natural bridge. Next comes the lake called Lethe, from which a beach of yellow sand extends to the Echo River. This stream is the largest of all; it is about three-quarters of a mile long, and its greatest breadth is about 200 feet.

In this region are the famous echoes which are a feature of this cave. The arched

passage varies in height between twenty and thirty-five feet, and the voice can create an harmonious prolongation of sound for an extreme period of thirty seconds after the original tone has been given out The long vault has a certain keynote of its own which, when firmly struck, arouses harmonies, some of them being of great depth and sweetness.

Formerly there were two routes by which visitors could see the caves: the long one taking about twelve hours and the short one taking about four. There are now four routes, arranged for the convenience of those who wish to inspect these wonderful subterranean cellars The first takes one past the Echo River and through the Mammoth Dome and the River Hall. The second includes the Rotunda, the Star Chamber, the Bridal Altar—where many weddings have taken place—and the Pillars of Hercules. The third includes the Violet City, the Marble Temple, and the Chief City. On the fourth route are Cleveland Avenue, Florists' Garden, the Valley of Flowers and the Maelstrom.

The Mammoth Cave is famous for its animal life The blind fishes that swim in its waters have been used by scientists and moralists, though from divergent points of view, as examples of how a faculty can decay for want of use Next in importance to these are the millions of bats that inhabit the outer galleries, and the insects in the cave have attracted the attention of the entomologist. In one of the caves mummies, said to belong to a race that lived here before the Indians came, have been found, and Chief Hall owes its name to the fact that here the Indian chiefs held their councils

Ewing Galloway, N Y

A fairy cave come to life—one of the beautiful " rooms " in the Carlsbad Cavern, New Mexico, 750 ft. below the surface of the earth

The claim to be the largest cave in the world has been made for the Wyandotte in the state of Indiana, which was used in 1812 as a saltpetre factory. It has only been partly explored, but its known passages extend to twenty-three miles, and 144 places have been named. Chief features include the Pillar of the Constitution, a stalagmite column, seventy-one feet in circumference, an immense room called Rothrock's Cathedral; the Pillared Palace, and Milroy's

Temple. The cathedral is 1,000 feet in circumference and both it and the temple, 100 feet wide and 150 feet long, possess an unrivalled array of twisted stalactites—"helictites" as they are called.

As this cave has no large streams and few pools or springs, its fauna and flora are not very extensive. Formerly bears, wolves and other wild animals took refuge in its fastnesses: and bats, mice, rats and salamanders are frequently seen. Blind crawfish have been found and there are many crickets. As in many other caves, remains of early man belonging to the Stone Age have been discovered.

The Luray Cavern

The Luray cavern in Virginia is another wonder of the world. Its stalagmites are as fine as those in any part of the globe, one being a column thirty-five feet high and elaborately draped. In the Giant Hall are several, each over fifty feet in length. But even more remarkable are the so-called cascades in this cavern. They resemble foaming cataracts that have been caught in mid-air and transformed into white or amber-coloured alabaster. The finest of them all is forty feet high and fifty feet wide; it is pure white and each ripple appears to have been polished. The Swords of the Titans are eight huge blades, each fifty feet long, but drawn down to a very fine edge. When struck heavily with the hand they fill the cavern with sounds like the tolling of bells. They are formed from carbonates trickling down a sloping and corrugated surface.

The Carlsbad cavern in New Mexico is another of the outstanding caverns in the United States; but there are many more, all equally wonderful, and thousands and thousands only a little less remarkable. But we must go on to deal with the caverns in Europe.

Almost every country in Europe has its caves. Those of Altamira in Spain have already been mentioned, and there are many in the Pyrenees. The limestone soil of France has many caves and some of these have yielded information that has helped enormously to build up the science of anthropology. The caves of Perigord are famous in this respect, and many British soldiers will remember the shelter given by the caves or cellars of Arras, used in normal times as wine vaults.

Of the European caves it is necessary to make a selection and four have been chosen for brief description, although it is well to remember there are many others equally beautiful and equally worthy of attention. The four to be dealt with here are the Blue Grotto of Capri, the Grottoes of Han in Belgium, and two groups less well known, at least to English travellers, the Domica and Macocha in Czechoslovakia.

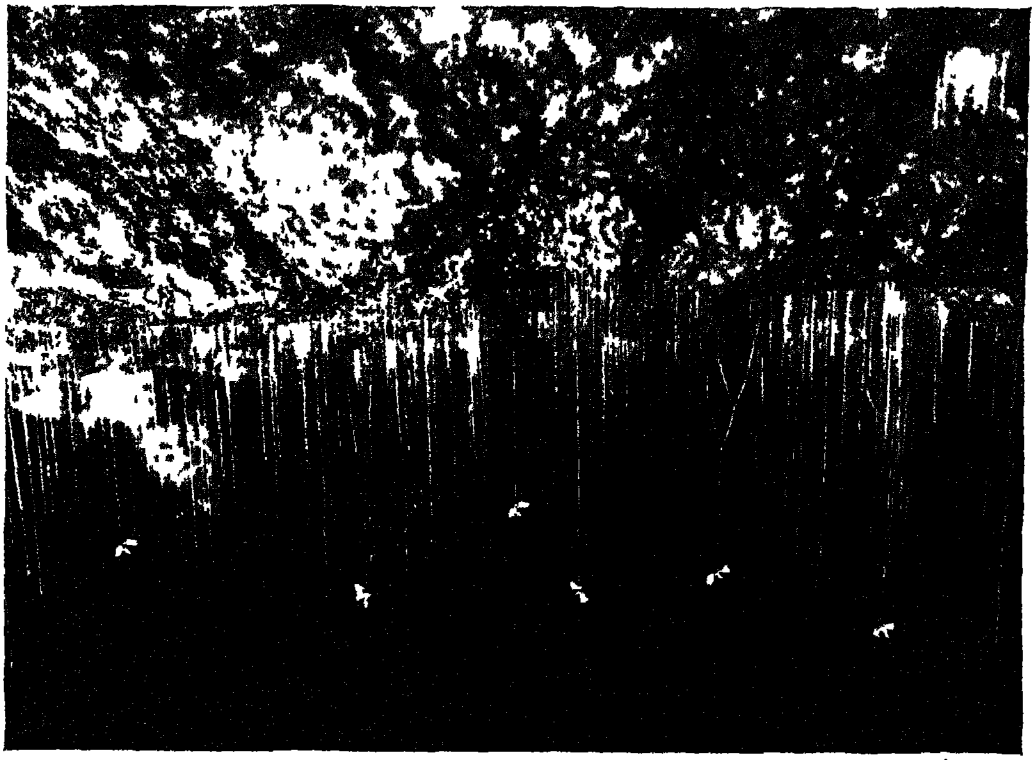
Beauties of the Blue Grotto

The Italian island of Capri has many caves around its coasts and one of these is that called the Blue Grotto. Into this the visitor is taken in a boat and, while being propelled along the waterway, he can admire the wonderful blue of the waters, in which are reflected the myriad figures that Nature has fashioned on the roof and walls of the cave. Though small compared with the American caverns it presents a scene of wondrous beauty. It was known to the Romans, but was then lost to sight for centuries until again discovered in 1826. Near it is a cavern in which the light is green instead of blue. The cause of this phenomenon is that the light enters by a small opening and is refracted to give a different colour —blue in one case and green in the other.

The Grottoes of Han, with which the neighbouring ones of Rochefort may be mentioned, are in Belgium in the beautiful region of the Ardennes, not far from Dinant and the Meuse. The Han grottoes consist of immense halls with roofs so high that the human eye can scarcely see them; for instance, that of the Dome Hall is 430 feet from the ground. Watercourses run through the caves and, as in many others, the visit is made partly in boats. The Hall of the Peaks is another of the grottoes, in all of which are accretions that Nature has made in such dazzling variety and splendour. The caverns are lit by electric light.

At Rochefort the grottoes are somewhat different. Here the caverns go deep down into the bowels of the earth. Their most notable feature is the Grand Hall of the Sabbath, with vertical walls rising to an immense height. These are illumined for the benefit of visitors by a fireball sent up by the guide. Another of the Rochefort grottoes is called the Palace of Bagdad.

In Moravia, now part of the republic of Czechoslovakia, there exists a subterranean world full of underground lakes and secret passages, magnificent halls and other rooms, all decorated with stalactites and stalagmites of a thousand wonderful shapes. It is a mysterious world into which rivers dis-



Courtesy of the New Zealand Govt.

In the Waitomo Caves, New Zealand, is one of the most remarkable sights in the world. Covering the roof and walls of a grotto, which is traversed by boat, are thousands of glimmering glow-worms which give the cave the appearance of being illuminated by pale blue fire. *A further peculiarity of the grotto is the number of slender silken threads lowered by the glow-worms to entrap insects*

middle of the 19th century this was explored by Sir W. Boyd Dawkins, and in it were found the bones not only of the hyena but also of the Irish elk, the great cave-bear, the lion and the woolly rhinoceros, as well as of a host of other creatures that roamed the land 40,000 or so years ago. From a study of the relics of man and beast, found in layers beneath the cave floor, the story of man's fight for life against his savage enemies has been reconstructed.

Caves used as a Store for Munitions

There are many other caves in various parts of England. For instance, the city of Nottingham possesses a number, but there is little to say of them. Under Chislehurst Common in Kent is a great network of caves extending for miles and even now not fully explored. During the Great War they were used as storehouses for ammunition, and afterwards were found suitable for the growing of mushrooms.

It would be indeed surprising if the rocky western shores of Scotland, with their hundreds of islands and islets, could not show something remarkable in the way of caves. In 1772 Sir Joseph Banks discovered Fingal's Cave. On the southern side of the island of Staffa, it is 227 feet long and sixty-six feet high. It is famous for its pillars, and from the rocks hang crimson, white and yellow stalactites. The sea forms the floor, and its murmur caused the inhabitants to call the cave by a poetical Gaelic name meaning the cave of music.

In suitable atmospheric conditions the cave's beauty is unique. The play of colour is exquisite, as the basalt combines every tint of warm red, brown and rich maroon; seaweeds and lichen paint the cave green and gold; while the lime that has filtered through has crusted the pillars here and there and tinted them pure white. Other caverns on Staffa are the Scallop or Clamshell, 130 feet long, on the south-east side of the island, and Boat and Cormorants' caves.

In our review of nature's underground wonders we now cross to the other side of the world: Australia and New Zealand possess

some remarkable caves. North Island, New Zealand, possesses a wonderful group called after Waitomo, a settlement near them. First explored in 1879, they consist of a series of lofty chambers in the heart of a wooded hill and are traversed by an underground river. They have two entrances, one where the river goes into the caves and the other in the middle of a thicket on the hillside.

Waitomo "Cathedral"

Of the separate caves the one called the Sculptor's Studio has statuary, figures and busts worked in the most delicate tints and tracery; while pillars of pure white support the roofs and corridors. Stalagmites and stalactites abound. The cave called Waitomo Cathedral has a massive dome and is noted for its acoustic properties; in it the five orders of architecture can be traced, and in another cave, the Organ Loft, there is in the limestone a figure very like an organ.

The finest of these caves, however, is that called the Glow-worm Grotto, which is without a rival, it is said, anywhere, and has been called the eighth wonder of the world. To see it, as at Capri, the visitor must take a boat, which is piloted along an underground river by means of wires suspended from the walls. Above is a scene, not unlike the Milky Way in the heavens, but much closer and in its way more remarkable. It is formed by myriads of tiny glow-worms which are attached to the roof and walls of the cave. Another cave is called the Blanket Chamber, because the artificial light with which the caves are fitted reveals a formation that could easily be mistaken for a gigantic hanging blanket.

Two other groups of New Zealand caves may be mentioned. The Ruakuri Caves, explored early in the 20th century, are larger than the Waitomo. Their halls and chambers are connected by winding corridors adorned with beautiful stalactites and stalagmites. Perhaps their most remarkable feature is the hidden waterfall, the echoes of which reverberate through the caverns as it thunders on its way behind an impenetrable wall of rock. The formations here are, in many cases, almost perfect replicas of articles known to the outside world. For instance, the series called the Bride's Jewels, as they scintillate and flash under the rays of the electric light, seem to possess all the attributes of the real thing. The Bridal Cake is another remarkable formation.

The Aranui Caves were discovered in 1
The entrance is situated in a bold outcro
limestone almost opposite Ruakuri, an
completely hidden in luxuriant bush thr
which a steep pathway has been cut. P
through a narrow portal, the visitor c
a lofty hallway hung with stalactites,
few yards farther on descends by a st
into a spacious chamber surrounded by m
striking formations. As in the other caves, Aranui appears to present a replica of almost every imaginable formation; and, aided by beautiful lighting effects, these are displayed to the fullest advantage. The Fairy Walk, Crystal Block, and Temple of Peace are a few of the outstanding features.

Some of the stalactites are of great size, and must represent ages of slow building up, drop by drop, from the dimly-seen roof overhead. In the Crystal Palace there are stalagmites up to twelve feet high and seventeen feet six inches in diameter at the base. Arches and balconies are draped in delicate-hued stalactites, while others form transparent partitions, flung into dazzling prominence by concealed lights. White shawls and blankets, which appear only singly in the other caves, are found here in profusion, the markings and colour effects being almost faultless. Figures representing statuary in an almost lifelike manner are to be seen on all sides. Summed up, the attractions of these wonderful caves of New Zealand have been described as: Ruakuri for weirdness, Aranui for beauty, and Waitomo for romance.

Nullarbor Plain

In 1935 there were explored some rema
able caves on the Nullarbor Plain, a treel
waste covering 30,000 square miles in So
Australia and crossed by the main railw
line running between Perth and Adelai
It was known that something of the ki
existed and spasmodic efforts had been mad
to pierce their mysteries, but nothing ver
important was done until the expedition
of 1935.

The exploring party went down by ladder into the Koonalda Cave, where they found an underground chamber about 800 feet in circumference. Passing out of this they walked over masses of rock for half a mile before reaching a small hole through which they crawled to find an enormous well, fifty feet in diameter. The impression of an aboriginal foot was seen in the sand. The party went along for a further half-mile before they were checked by the presence of water.

Marvellous limestone formations of fantastic shape and size in a newly-explored cave in the mountains at Jenolan, New South Wales

Other caves were explored, too. In one case a canoe was lowered down the face of a cliff, eighty feet high, to a waterway along which the party travelled. Soon they found a great lake, the water of which was more than 200 feet deep. One of these caves has at its entrance some red marks made originally by outstretched fingers, but afterwards maintained by red ochre. It is believed that long ago the aborigines of the region used this cave for their secret rites.

Another remarkable group are the Jenolan Caves in the state of New South Wales, something over 100 miles from Sydney. Like many others they are in a limestone region, which contains several other groups almost equal in interest. The stalactite formations in the Jenolan caves are perhaps their most remarkable feature, many of them being pure white and all being extremely beautiful. Something of their weird and fantastic charm can be gathered from the picture on this page.

CHAPTER XIV

HOW MAN DELVES INTO THE EARTH

THERE are many dangerous occupations that have to be carried on to endow us with the comforts and necessities of life, but one of the most perilous is coal-mining. In spite of legislation intended to protect the lives of the men who work the coal seams, coal-mining is still—and always will be—an extremely hazardous undertaking.

Coal, as everyone knows, is composed of the remains of the plants and trees which, owing to subsidences in the earth's surface, were buried. Long after, other forests grew over the graves of the buried trees, and in the course of time these in turn died and became covered and another growth of vegetable life followed (*see* FRONTISPIECE). The process may have occurred three, or four, or even many more times, and the coal we burn to-day represents the stored-up energy of the vegetable life of some previous age. The coal formed in each age lies in a layer by itself with shale and rock both beneath and over it; then comes another layer of coal and another layer of shale or rock, and so on.

It is generally believed that the Romans were the first in Britain to make use of coal, but their demands must have been very slight, and not until the 14th century was there any serious call for this fuel. The first efforts at mining it were to remove the top surface of earth covering the outcrop of a seam and to excavate the coal in much the same way that quarrying is carried out to-day. Later, shallow pits were sunk and widened out at the bottom to a cavity where miners hewed out the coal, which was then drawn to the surface in buckets. This type of excavation was called a "bell" or "bee-hive" pit.

The Difficulties of Deep Shafts

Surface working can only be carried on for a short while because the coal accessible is soon used up; and men sought a way of obtaining the more deeply buried and richer deposits. To attain their object deeper shafts had to be sunk, and nearly always the chief obstacle to working deep seams was w. r. Underground streams were continually being encountered, and whenever a shaft was sunk a tunnel had to be dug from its bottom to the nearest valley so that the water could be drained away. This method of mining and draining was utilized right to the time of the Industrial Revolut when the greater demand for coal to dri the steam engines in factories led to m intensive mining.

The early 18th century saw the use o gunpowder for blasting, thus enabling th coal to be won more rapidly, but always water was the chief enemy and many mines had to be abandoned because the lower workings became flooded. Then Newcomen's pumping engine was invented (1705) and at last it was possible to get rid of the water; many flooded workings were reopened, and newer and deeper shafts were begun.

Perils that Beset the Coal Miner

But the elimination of the water problem and the sinking of still deeper mines brought with it another problem: that of ventilation. Man cannot work without a sufficient supply of pure air, and many of the tunnels lead off the main shaft received insufficient enable the miners to breathe comfortal Lighting, too, was a problem, for cand ignited the dangerous gas called fire-dan found in varying quantities in every min Explosions and loss of life were frequent, an in the more dangerous mines the only "ligh that could be used with any degree of safe was provided by a notched wheel—calle a steel mill—which produced a shower sparks.

Then came the 19th century and with improvements, in methods and applianc that revolutionized the coal-mining industry The two most important innovations were the introduction of the safety-lamp and the sinking of two shafts instead of one. The first made it possible for miners to work in comparative safety from explosions, and the second allowed the mines to be ventilated and made them less like death-traps. By an Act of 1887 the second shaft was made compulsory.

Fire-damp or marsh gas is still a menace. Nearly all the terrible disasters that have occurred in coal mines have been due to this gas coming in contact with a naked light, and in the 18th and early 19th centuries it was an all-too-frequent occurrence for explosions and death to result from its presence in the mines. Dr. Clanny introduced a safety-lamp in 1813; George Stephenson

Gruelling work fraught with danger every hour of the day. Extracting coal from the face, half a mile underground, and hitching trucks (*top*) at the Powell Duffryn Pit, South Wales

and Sir Humphry Davy independently invented safety-lamps: and Clanny later brought out one on Davy's principle, substituting, however, a glass cylinder at the lower part for the gauze in the original type. The fine wire gauze conducts the heat away too rapidly for flame to pass through, although gas will pass into the lamp and burn there around its flame. The safety-lamps of to-day are modelled usually on those of Clanny, Davy or Stephenson.

How Coal is Located

Though it may be known where coal is lying, perhaps a few hundred feet below the surface, the mining engineer has to find out many other things before he can begin to win the coal. He must discover how far down the seams are, how thick they are, at what angle they run in relation to the surface, and what is the nature of the strata above and between the coal seams. To obtain these facts he bores a hole a few inches in diameter deep down into the earth, and the core cut out and brought up by the drills tells him what he needs to know.

After that, the first stages of developing the coal mine begin, with the sinking of two deep shafts, generally circular in section and about twenty-five feet in diameter. These two shafts are called the "down-take" and the "up-take," because fresh air passes down the former, ventilates the mine, and is drawn away by means of a fan through the up-take. At the bottom of the latter shaft is a water-pump, used to drain water away from the mine and pump it through a pipe rising through the up-take to the surface.

The first stage of sinking a shaft is simple, since to a depth of about twelve feet the top surface can be removed by hand. After that depth has been reached it becomes necessary to remove the soil by means of an overhead gear carrying a bucket, until at last solid rock is laid bare. There are a number of ways of sinking a shaft below this level, for every type of strata is dealt with in a different way. If the strata is fairly dry it is drilled and blasted out by hand, the shaft being lined with wood cribs and later encased with brick. If the strata is very loose and carries with it a good deal of water, it may be subjected to a freezing process. A series of holes is drilled, outside the circumference of the pit shaft, into which are inserted pipes which are all connected up. A freezing mixture, such as ammonia, is then circulated through the pipes, thus freezing the water in the strata and making it possible for the material to be drilled away by hand and removed. This avoids the necessity of pumping away large volumes of water continuously.

A third method, which also is employed when dealing with water-bearing strata, is the pneumatic method. In this case a caisson is used, supplied with compressed air, and the sinkers excavate inside it. The water cannot enter the caisson because of the air within being at a relatively . pressure. In all cases, of course, the walls of the shaft must be lined as the latter is sunk, otherwise they may cave in on the workers.

The bottom of the shaft, when it is reached, is widened out so that the main haulage roads can be set out. When these are completed it is possible to begin digging out, or "working," the coal. As a rule that in the vicinity of the shaft is left unworked, to form a support for the shaft and the buildings around it on the surface.

The direction of the main haulage roads in a coal mine is dependent on what is called the "dip" of the mine—that is, the angle which the coal-beds make with the horizontal plane. From these main roads the miners burrow left and right, using picks and shovels, loading the coal into tubs which are then transported to the haulage road; hence they are conveyed by means of trucks to the shaft, where they are carried to the surface in the cage. The latter is operated by means of a powerful winding engine at the pit-head.

The haulage roads are more substantially built than the chambers containing the coal-faces: they are very securely timbered and are often arched with brick and stone to prevent subsidences. From these main roads there lead the headings where the miners work, and smaller passages branch off from these again.

Always as the miner delves deeper and deeper into the coal seam he must take measures to support the roof and sides of his burrow as he goes along. A delay in timbering may mean a collapse of the roof, followed, if not by death, then by serious injury.

Shot-firing and Coal Cutting

The miner's life is one of constant danger. It must not be imagined that all he does is to wield a pick and shovel. Actually most of his time is spent in drilling holes for firing "shots" to loosen the coal. In working soft coal the miner may use a hand boring machine, but nowadays machine borers are

more often employed. Another modern tool used in coal getting is the chain-cutter; this cuts horizontally along the top of a coal seam, another machine cutting along the bottom. In this manner the coal is separated from the layers of rock above and below it. Holes are then drilled into the coal, charges of explosive being inserted and fired. If the chain-cutter were not first employed the rock would come away with the coal and would have to be separated from it later.

The boring of shot holes is not so simple a task as it might appear, and only a skilled worker knows in what direction and to what depth he should make the hole. He must always fix his charge so that it will act in the weakest line. Explosives used in mining are made up in cartridges, weighing from three to five ounces, which are pushed into the drilled hole with a wooden rod, a detonator being inserted in the neck of the topmost cartridge. The shots are fired by safety fuse or by electricity. In the latter case the detonator is fitted with short wires which are connected by a cable to an electrical machine at a distance.

An old and dangerous method of firing the charge was by means of what were called "squibs," made by filling straws or paper cones with fine gunpowder. Touch paper, made by soaking ordinary paper in saltpetre, was also employed. It is not altogether surprising that this form of firing caused many accidents. Even to-day the firing of charges may be fraught with danger if due precautions are not taken—and even when all the usual safety measures are adopted. Thus there may be some latent defect in the cartridge itself, and should the particular charge be one which has been pushed some distance into the bore, those at the outer end may explode while the defective one merely remains in a state of dormancy. Then later, perhaps, while the miners are getting away the coal, the defective charge may explode with disastrous results. Lack of due care in placing the charges may also lead to similar trouble. Sometimes, though rarely, the coal may get to the domestic fireplace still carrying within it a portion of the explosive, with dire results.

No mine is a pleasant place in which to

Despite all precautions, mine accidents still occur too frequently and highly-trained rescue squads are always ready for an emergency. Here a rescue worker is seen crawling through a narrow ventilation shaft

work, but the deeper the mine the greater is the discomfort due to the heat and the difficulty of adequate ventilation. The deepest mines in Britain are in the Lancashire coal-field, the Pendleton Colliery, for example, being worked 3,500 feet below the surface. In South Wales is to be found the largest coal area in Great Britain. It covers about 900 square miles, and the coal measures are as deep as any in the world.

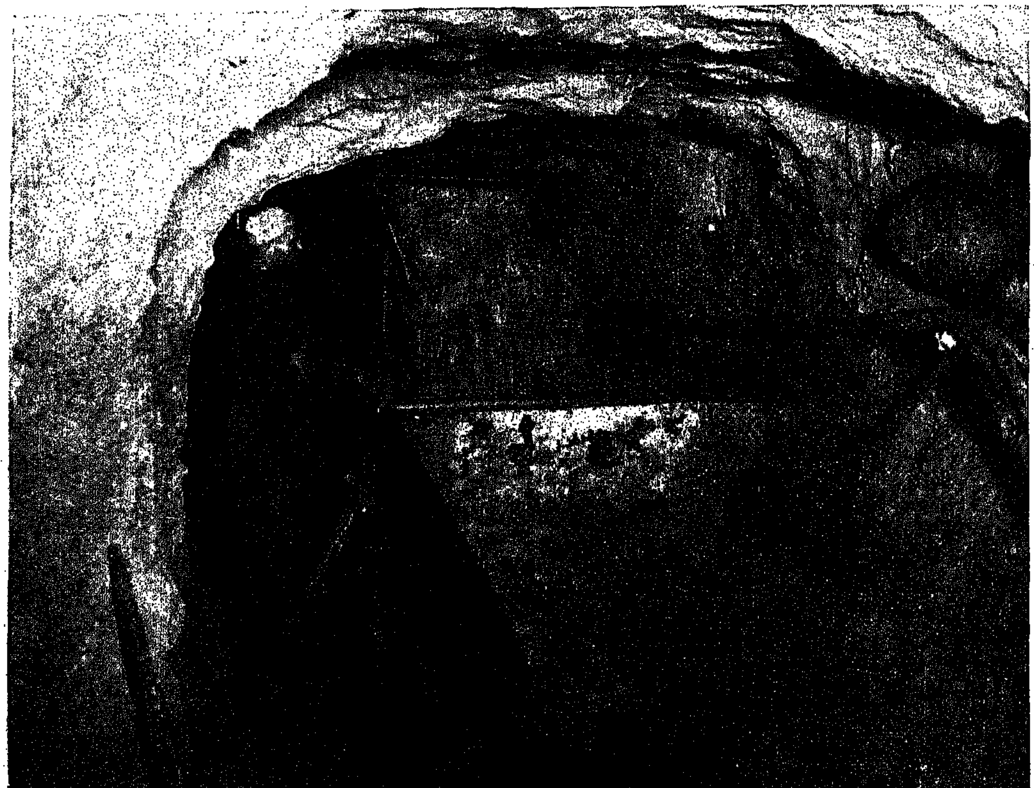
The Cumberland coal mines are of particular interest because they show the extent to which man will carry his determination in attaining a definite object. The coal seams at Whitehaven run right out under the sea

—a perfect maze of workings, reached by horizontal roads extending two or three miles beneath the floor of the ocean. The roads are driven from several points at a depth of 600 to 900 feet. One of the most terrible of mine disasters occurred in 1837 at Workington, near Whitehaven, where the coal workings ran 1,500 yards under the sea. The seams inclined upwards towards the sea and were worked to within 150 feet of the sea floor. A change of colliery managers led to the removal of some of the pillars supporting the old workings, and although many protests were made still more pillars were removed. Then late in November of that year the sea burst into the galleries: over forty lives were lost and the workings permanently submerged. The seams at Whitehaven dip away from the floor of the sea and are therefore quite safe to be worked, the main difficulty being that of ventilation.

Diamond mines are vastly different in appearance from coal mines. They are large funnels, oval in cross-section, which are believed to be the craters of extinct volcanoes. The depth of these funnels is unknown, but they go down very far and appear to have been filled up from below by volcanic mud. How diamonds are formed is still a mystery although it is known that they must be older than the rock in which they are found.

The surface of the mines is covered with a few feet of red sand, beneath which is a thick layer of limestone, and below this again is the diamond-bearing rock. The latter is of two kinds, distinguished by the terms "yellow ground" and "blue ground," the former lying nearer the surface to a depth of about 50 feet and the latter being of unknown depth.

Diamond mines are opened up by removing the outer surface and leaving the blue ground uncovered. Then by means of galleries let into the ground the workers drill into the diamond-bearing rock and blast it away. The blue ground is then brought to the surface, where it is spread out on level stretches of ground called "floors," from which bush and grass have been removed and

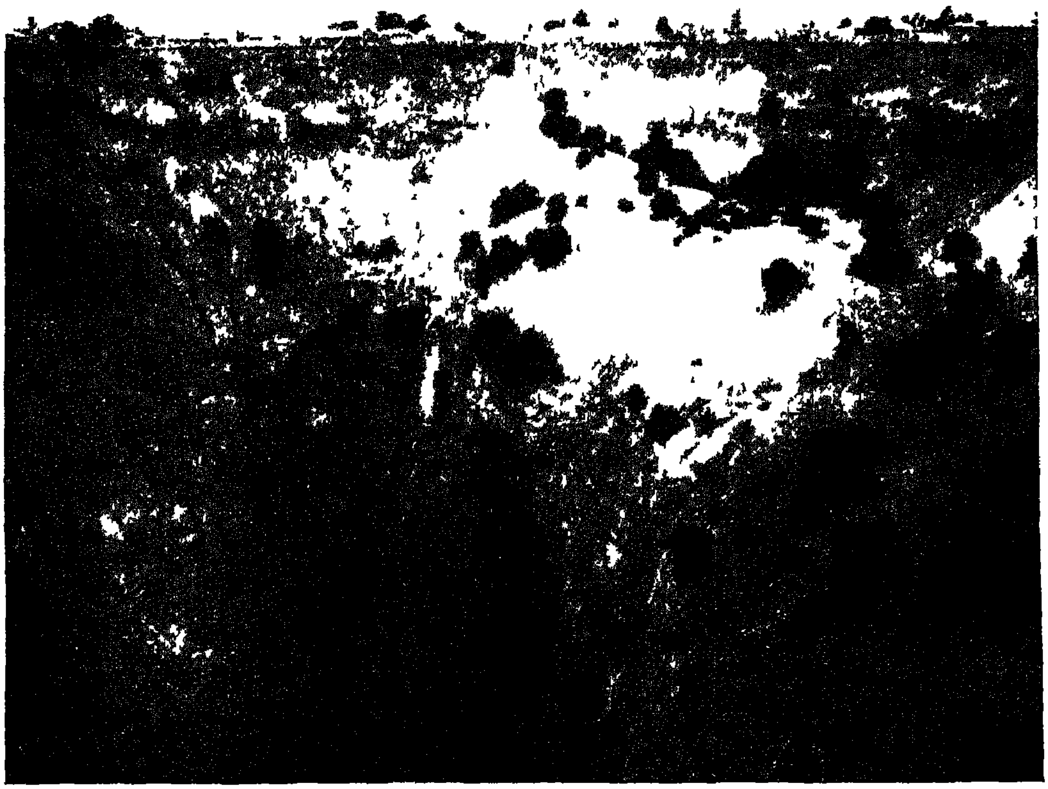


Courtesy of the Australian National Travel Association

Delving into the earth for the most precious metal; loading a truck with ore in a tunnel of the Kalgoorlie Gold Mines in Western Australia

which have been smoothed by heavy rollers. These floors in the De Beers and Kimberley mines stretch for thousands of acres: over them, to a depth of about a foot, the blue ground is laid, and left there for sun and rain to do its work in making it crumble. To hasten the process, the blue ground is harrowed by means of tractors, thus giving an agricultural aspect to the scene.

The time required for disintegration varies from about three to six months, depending



E.N.A.

The famous "Big Hole," at Kimberley, where men dug for diamonds in the early days of the mining town, was abandoned over a quarter of a century ago. But Kimberley flourishes and with the rest of South Africa now furnishes the great bulk of the world's supply of the precious stones

on the climatic conditions. When the process is completed the blue ground is loaded on to trucks which convey it to hoppers, where it is fed automatically into revolving cylinders which wash it thoroughly. From the washing-machines the diamonds and heavy minerals which are left pass into a chute and are conveyed to a sorting-machine fitted with screens by which the various sizes of diamonds are separated.

Whenever explosives are used there is always a danger to human life, but in diamond mining it is the moral danger which is chiefly prominent. The native workers cannot resist the temptation to smuggle diamonds out of the workings, but most of their devices for doing this, original though they were, are now known. A favourite method formerly was to swallow the stones, and on one occasion no fewer than twenty-one diamonds were swallowed by a native.

One of the greatest problems of modern times is how to deal with the vast increase of traffic in our cities. London faced the problem at the end of last century by creating the "tube" railways; and as the congestion above ground has become greater, more tubes have been built until now these underground arteries of passenger transport connect all the main points in London with the outer environs.

The first of the London tubes was the City and South London, begun in 1886 and opened in 1890; it ran from King William Street, under the Thames to Stockwell.

Various extensions have been added from time to time until now it goes from Edgware to Morden. The "Twopenny Tube," or Central London Railway, was opened in 1900, running from the Bank to Shepherd's Bush.

The building of a tube railway is a tremendous undertaking that involves great engineering skill. Of its difficulties and its dangers little is to be seen at the surface, however. The only noticeable feature at the shaft head is a wooden erection in the road within which may be discerned a steam crane hauling up earth and depositing it in carts. Far below, the tunnel is being carved out by a rotary excavator or by an hydraulic ram called the Greathead Shield. The type of machine in use depends on the nature of the soil through which it has to make its way. The rotary excavator can only be used for clay and can cut through that type of earth at just about twice the speed of the Greathead Shield. The latter, however, can make its way through even the hardest soils.

The survey and the preliminary calculations are made and the working plans prepared. So accurate is the work that in a tunnel of half a mile there would be a permissible deviation of only 1¼ inches. Before tunnelling operations commence, a service shaft is sunk to the required depth at various points along the route and lined with cast-iron rings formed of segments bolted together. At the bottom of each a chamber is made to accommodate the driving shield. Several segmented rings to line the tunnel are placed in position and the shield adjusted so that it can get a good firm start from the last of them. The shield, which has a steel cutting-edge, is forced by water power into the soil; the earth, etc., finds its way out through a hole in the face of the shield and is shovelled away. As the shield moves forward another section of the tunnel lining is added behind it, and so on throughout its entire journey. Behind the walls and between each segment liquid cement is injected.

The Severn Tunnel

The tunnel under the Severn, roughly four and one-third miles long, was begun in 1873, by the usual methods for this type of work; a smaller tunnel called a heading was made, which afterwards was to be enlarged to the finished size. As the soil was dug out the roof and sides were timbered temporarily and a brick lining added.

It was anticipated that a quantity of water would seep through the bricks, and as the tunnel was designed to slope downwards to the middle of the river and up again on the other side, arrangements were made for draining at the midway point. A shaft was sunk on the Monmouthshire side of the Severn and from it a small tunnel was driven upwards to the portion of the main tunnel that would require draining. Thus any water that found its way to the centre section would flow down the small tunnel to the Monmouthshire shaft, where it could be pumped away.

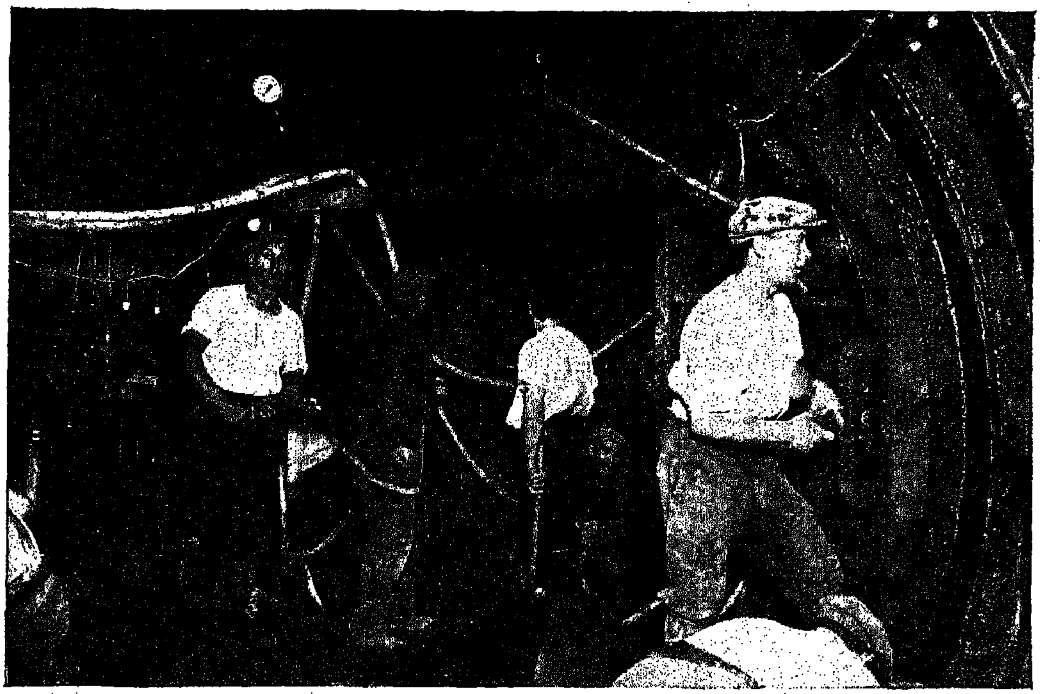
Drainage Difficulties

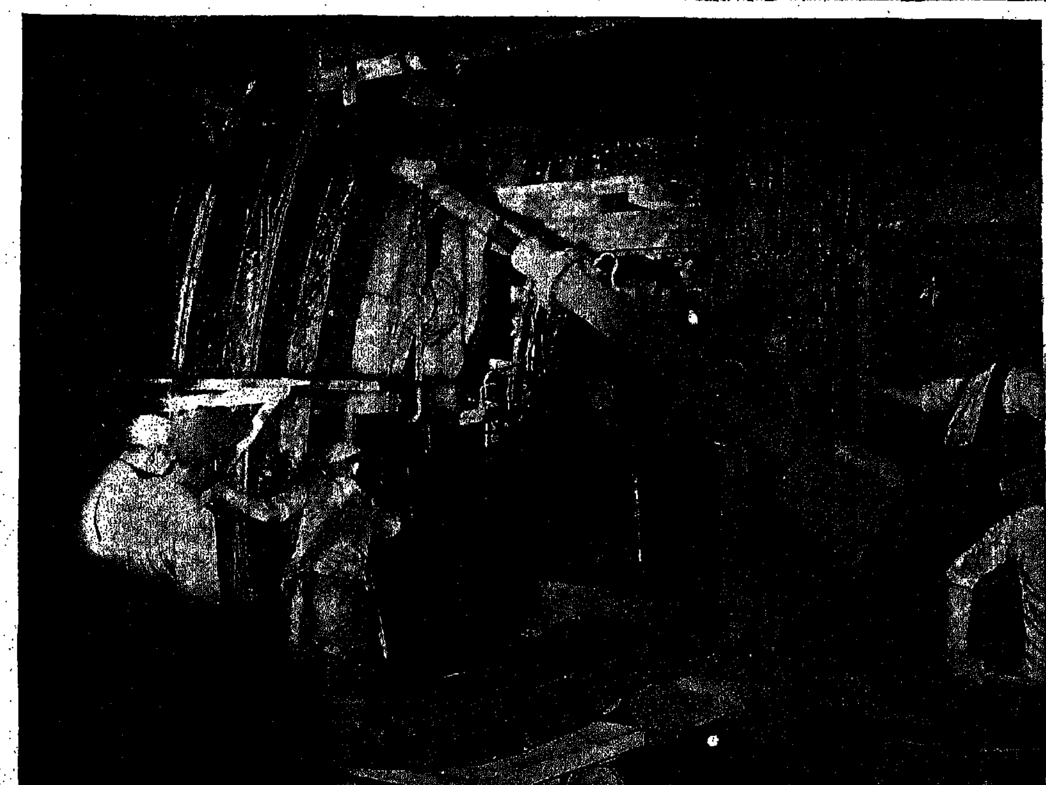
Quite near the first shaft a second one was sunk and another one on the Gloucester side of the tunnel, both being lined with cast-iron plates. Work started from both sides of the Severn, and went on slowly but steadily for some years. In 1879, when the Monmouthshire heading was within 130 yards of the Gloucester heading, by some strange mischance an underground water course broke in. Within twenty-four hours the whole of the workings were flooded and the task had to be abandoned for over a year. When the work was recommenced it was necessary first to pump away the water from the headings, and after a number of attempts a diver got along the tunnel to close an iron door there.

By sinking three new shafts and fitting newer and larger pumps the workings were drained. The following year the Severn itself broke through and flooded the tunnel, but by clever work the leak was stopped; the water was again pumped out, and the excavation proceeded. In 1883, again, the underground water course found a way into the workings and a week later a tidal wave swept up the Severn estuary, flooded the surrounding country and extinguished the fires in the pumping station. Eighty-three men were trapped in the tunnel, but were rescued in the nick of time.

No further mishaps occurred after this and the tunnel was completed in 1885; by the end of 1886 it was in use both for goods and passenger traffic, since when the Great Western Railway engines have thundered through it day and night on their journey from London to Cardiff. It reduced by fifteen miles the distance between London and South Wales.

One of the first sub-aqueous traffic tunnels was that under the Hudson River between New York and New Jersey, first projected





Courtesy of London Transport

Boring London's tubes. The Greathead Shield (*top*) carving its way through the earth, to be followed by the segment erector (*bottom*), which fits the tunnel with a cast-iron lining, or tube

in 1899 and eventually opened in 1927. The Holland tunnel is really a double one, the North tunnel being 8,557 feet long and the South tunnel 8,371 feet, not including approach roads. Under the river, the outside diameter of each tunnel is twenty-nine feet six inches, and the inside diameter three feet less. The width of the roadway is twenty feet, on either side of which is a footpath; there is head room of thirteen feet six inches. The tunnels were excavated by means of shields similar to those already described, and were lined with cast-iron segments.

Perhaps the most interesting feature of the tunnel, however, is the system of ventilation, made necessary by the fouling of the air by exhaust gases from petrol- and oil-engined vehicles. Each tunnel is divided into seven sections and each section has three fan sets —one blower, one exhaust, and one reserve fan. The fans are capable of supplying 3,760,000 cubic feet of fresh air per minute.

The Mersey tunnel, linking up Liverpool and Birkenhead, has a cross-sectional area of 1,680 square feet; its total road length, including approaches, is 15,191 feet; its external diameter is forty-six feet three inches, and its internal diameter forty-four feet. The width of the roadway is thirty-six feet, and there is provision for two lines of fast motor-traffic down the centre with a line for slow traffic on either side.

With the exception of two short lengths, the entire tunnel is cut through rock. Two shafts 200 feet deep were sunk on either side of the Mersey, and pilot headings fifteen feet by twelve feet were carried through from each end. The main tunnel was then excavated by enlarging the pilot tunnel. Holes four feet deep were drilled into the rock, which was blasted away by gelignite.

The tunnel is ventilated by means of a fresh-air duct under the roadway. Six ventilation stations, equipped with thirty fans, provide an aggregate of two and a half million cubic feet of fresh air per minute.

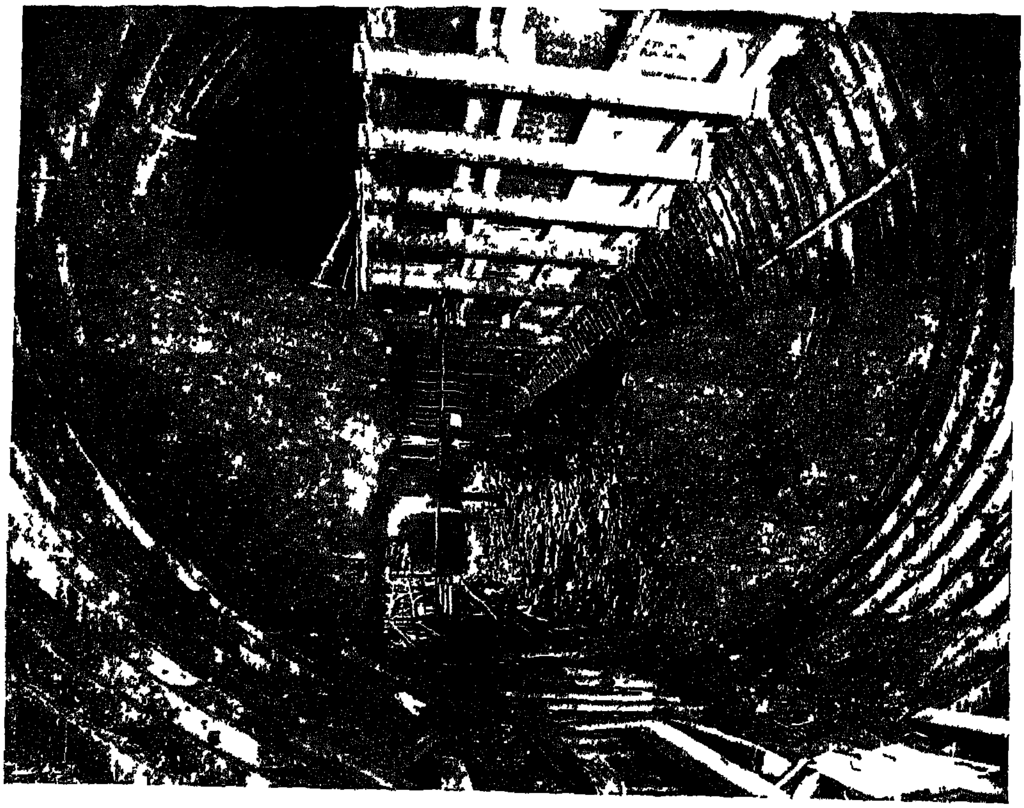


Photo: Stewart Bale

Tunnelling below a great river—part of the Mersey Tunnel in the course of construction; about 1,200,000 tons of rock were excavated. It is the largest under-water tunnel in the world, with an internal diameter of 44 ft., and links Liverpool and Birkenhead with a splendid roadway 2·13 miles in length. *(See also illustration in Chapters XL and XLIV)*

Photo Lauri, Bern *Courtesy of Swiss Federal Railways*

The successful completion of the St. Gotthard Tunnel in 1882 was a notable engineering triumph over almost insuperable difficulties. Entering the mountain side at Goeschenen in the north, the railway emerges 9¼ miles farther on at Airolo

It was in 1857 that the Mont Cenis tunnel was first mooted and pending the construction of suitable machinery for the great task it was begun with hand labour. Since its length was to be seven and a half miles, great care was necessary in working out the exact direction the tunnel was to take, for even a slight error in calculation might have meant that the two opposite headings would not meet. As it turned out, however, when the junction was made the centre lines were only a few inches out of coincidence—a marvel of engineering.

From 1857 to 1861 the excavating was done entirely by manual labour, and when in 1861 the special machines were employed, there was continual trouble with them. Progress was very slow, at an average of only eighteen inches per day—less even than hand labour could accomplish. In the following year, however, the average rate of advance was increased to three feet nine inches per day. In the light of experience the machinery was improved; although after seven years' work it was anticipated that the tunnel could not be finished until 1875, it was actually completed in 1870, thirteen years from the commencement. The Sommelier machines employed in this work consisted of a number of drills, or perforators, worked by compressed air. They were driven into the rock to a depth of about two feet six inches when they were withdrawn, the holes were cleaned out and charged with gunpowder, and the rock disintegrated by blasting. By such methods was a tunnel cut right through the heart of the Alps between France and Italy.

The St. Gotthard Tunnel

As far back as 1838, when the first railway was constructed in Switzerland, it was proposed to connect the railroad with Italy, and the St. Gotthard route was one of those suggested. It was not, however, until 1872 that work on the railway was begun. The tunnel on this route goes through the St. Gotthard Mountains, from Goeschenen, on the Reuss, to the village of Airolo on the banks of the Ticino. Its length is over nine and a quarter miles. The contract for this gigantic task was in the hands of one man, M. Louis Favre. The charge that broke through the rock separating the two sections of the tunnel was fired on February 29, 1880, and the two portions were found to meet exactly.

Favre did not live to see this happy day, for in 1879 he died of apoplexy.

The St. Gotthard is a wonderful feat of engineering, even in this age of wonders; in view of the comparatively primitive type of tools used, the rapidity with which it was constructed is remarkable. The northern end is 3,638 feet above sea-level and the southern end 3,756 feet, but the centre of the tunnel is higher still, 3,786 feet, the track sloping down towards the two mouths. A great deal of difficulty was experienced owing to subterranean torrents being tapped and, at the southern end, for a whole year, the work had to be carried out in distressing conditions. Then in another part of the tunnel, owing to the nature of the rocks, large masses were displaced and threatened to cause serious obstructions. Heavy timbering was employed to prevent the fall of rock but it was found useless and was replaced by solid stone. This again failed; so did a second vaulting of stone and a third, but eventually the difficulty was overcome and the tunnel stands to-day as one of the engineering wonders of the world.

Joining Switzerland and Italy

The Simplon tunnel was begun in 1889 and completed in 1905. It consists of two single-track tunnels fifty yards apart, connected at intervals by transverse galleries. The total length of the tunnel is twelve and one-third miles, and like the St. Gotthard it slopes away from the centre towards either end—to Baffi at the Swiss mouth and to Iselli in Italy.

In constructing the Simplon tunnel one of the greatest difficulties was the great heat experienced at the centre. In order to reduce the temperature so that it would be possible to carry out the work, two engines each of 200 horse-power were installed at either end, each driving a fan twelve and a quarter feet in diameter, which forced the air through a fourteen-inch pipe to the working-face. As the headings went deeper and deeper into the mountain, the pipe was extended along the top of the roof. Even then the temperature exceeded anticipation and ice-cold water had to be sprayed on the surface of the workings. The machines employed in excavating the Simplon were invented by the contractor M. Brandt who, like M. Favre of the St. Gotthard, died before he could see the completion of the enormous enterprise.

After such stupendous tasks as the great railway tunnels we have described, it would seem a much simpler matter to drive an underground aqueduct, yet occasions have arisen when the latter undertaking has proved so difficult that those engaged on it have abandoned the project. In 1880 work was begun on a scheme to use the waters of of Vyrnwy, a tributary of the Severn rising in the mountains of North Central Wales, to supply the needs of Liverpool. With this end in view the Llanwyddyn valley was dammed to create a reservoir capable of holding 12,131 million gallons. The aqueduct conveying the water is sixty-seven miles long and a very small part of it—only 900 feet—was composed of tunnelling, yet the difficulties in constructing this small section of the work held up the completion of the whole scheme for nearly four years.

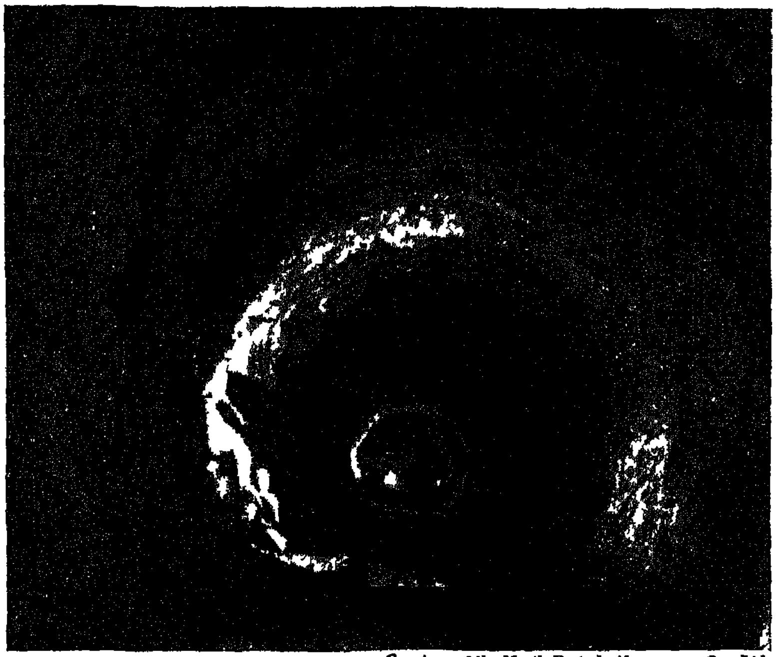
The original plan had been to lay pipes in the bed of the Mersey, but the Parliamentary Committee concerned would not permit this and, in consequence, it was decided to drive a tunnel beneath the river. Owing to the loose nature of the river-bed it was necessary to carry the tunnel at a fair depth and shafts were sunk to fifty feet, but the contractors had proceeded no more than fifty-seven feet in their boring when they gave up the task. Another contractor took over the work and drove the tunnel 182 feet from the Lancashire side, when he also abandoned it; eventually the Liverpool Corporation engineer himself resumed the work and completed it satisfactorily.

The whole cause of the trouble was the difficulty in keeping the water away from the working face. The shield, encountering a water-logged mass of earth, was unable to make any headway and at one stage of the work it actually collapsed. The Corporation engineer met with the same trouble but managed to overcome it, and to carry the tunnel to completion.

Other aqueducts are dealt with in Chapters XII and XXXVI.

Artesian Wells

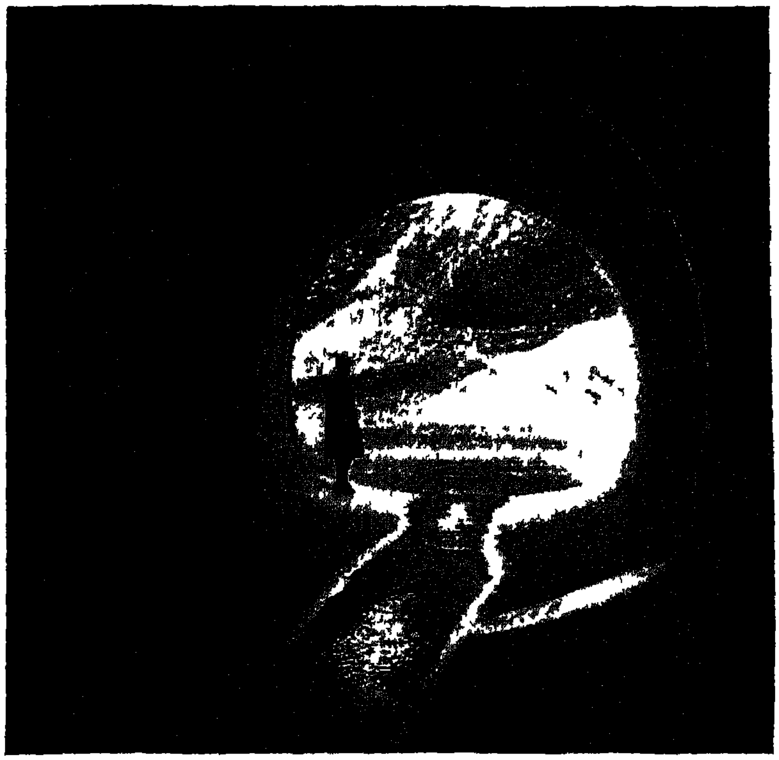
One needs only to dig a foot or two below the surface of the soil to discover that the ground is soaked in moisture; but it may seem mysterious that while one may sink a well and get only a poor water supply, a boring not far distant may yield water in abundance. Whether or not water will be tapped depends on the formation and nature of the underlying strata, and the engineer experienced in sinking wells knows where he may reasonably expect to obtain a good water supply. It is common, too, for the aid of a water diviner to be sought in locating underground water.



Courtesy of the North British Aluminium Co., Ltd.

Everyone is familiar with the wells found in rural districts, but although these prove useful they are often suspect, for there is always the danger of the water becoming contaminated. The supply of water is fickle and uncertain and in time of drought may fail altogether. In the artesian well, however, man has found a way of obtaining a purer supply and a greater volume of water. The artesian well will supply anything up to five million gallons of water a day, depending on the source it taps. The name is said to be derived from Artois, where the first artesian wells were sunk.

Far below the site on which London is built is a huge natural basin formed of an impermeable soil such as clay. The basin itself was produced by a folding of the strata in long ages past, by which the edges of the layers were brought up to the surface. Over the clay layer are others of porous materials such as sand, gravel or chalk, alternating with non-porous layers of clay and so on. Surrounding the rim of this are elevations where the porous layer is exposed. Rain falling here finds its way into the basin until it saturates it right up to its rim, being prevented from escaping by the impervious clay beneath. Now if we drill a hole into the ground until it enters



Driving tunnels to carry water: outlet end of the aqueduct connecting Loch Laggan with Loch Treig, part of a big hydro-electric scheme in Scotland, and (*top*) view, during construction, of the 15-mile Lochaber tunnel which carries the combined waters of the lochs to the power-station at Fort William

the water-soaked layer at the lower part of the basin, we may expect the hole to fill up with water. Moreover, if the level of *the ground where we sink our hole is lower than that at the rim of the basin* we may expect the water to spurt up into the air.

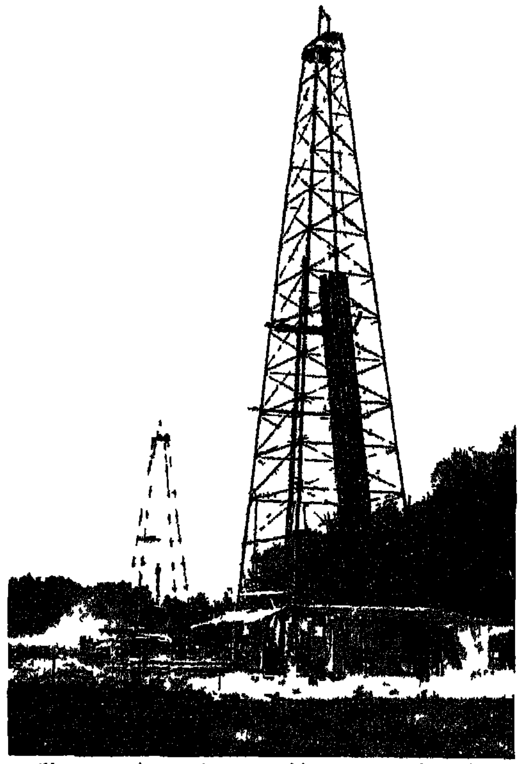
This is exactly what happens when an artesian well is sunk, and round London hundreds of them contribute millions of gallons a day to its water supply. The depth to which such a bore must go depends on how far down these natural basins lie. Round London it is only necessary to bore to a depth of three or four hundred feet; but in some localities depths of one, two, three or four thousand feet may have to be reached before an abundant water supply can be tapped. In Queensland, Australia, wells to a depth of about 5,000 feet have had to be bored.

How an Artesian Well is Bored

The method of sinking artesian wells varies a great deal. One process is similar to that adopted to discover the nature of the various strata before sinking a shaft for a coal mine. A diamond drill is used, and as fast as the hole is made it is lined with steel tubes until the chalk layer is reached. If the bore were not lined, impurities from the softer soils through which it passes would seep into the water.

Another boring system is called the percussion method. Here various kinds of tools are attached to long rods which work up and down with a reciprocating action, pounding away the earth and rock or other strata until they form a "sludge" with the water supplied to the tool. This semi-liquid sludge is brought to the surface by a pump and the process repeated. The diamond drill, however, is always used if at all possible. If the water from an artesian well does not rise naturally to or above ground level, lift pumps are employed to raise it to the height required.

An interesting feat of well-boring was carried out at Grenelle, Paris. From



Drilling into the earth for drinking-water. At Aulnay-sous-Bois, France, an Artesian Well has been sunk which reached a depth of 2,700 ft. before water was tapped. View of the workings and (*bottom*) water gushing from the well at a temperature of 93 degrees Fahrenheit, after 3 months' boring

consideration of the geological formations, the engineer came to the conclusion that he would have to sink a bore over 1,000 feet in depth and that when he had tapped the supply the water would rise considerably above ground level. The task occupied eight years; after boring through thirty-three feet of gravel, 100 feet of sand, clay and lignite, sixteen and a half feet of mixed chalk and clay, 1,378 feet of chalk, eighty-eight and a half feet of chalk marl and 186 feet of gault clay and greensands, the water gushed out to a height of 122 feet above the ground. This well still contributes about 800,000 gallons a day to the Paris water supply, the temperature of the water being 81·81 degrees Fahrenheit when it comes to the surface.

CHAPTER XV

DRAGONS AND SERPENTS OF TO-DAY

THE dragon is one of the most ancient and the most widespread monsters that the imagination of man has called into existence. As Apep, the snake-god, it appeared in the complicated pantheon of Egypt; the inhabitants of Babylonia and Chaldea knew it as Tiamat, goddess of primeval darkness and chaos, while in the sacred books of the Hebrews, and still more in the numerous myths, allegories and legends of the Middle Ages, the dragon—symbol of the powers of darkness—played a very prominent part. In the Far East it is even to-day a favourite motive in works of art, and for centuries it has served as the national symbol of China. In our modern sophistication, we scoff at dragons and at all their numerous and fantastic companions in wickedness, but to the terrified imagination of our forefathers they were very real creatures, who must be propitiated or else boldly overthrown, if the destruction lurking in their teeth and claws and fire-laden breath were to be averted.

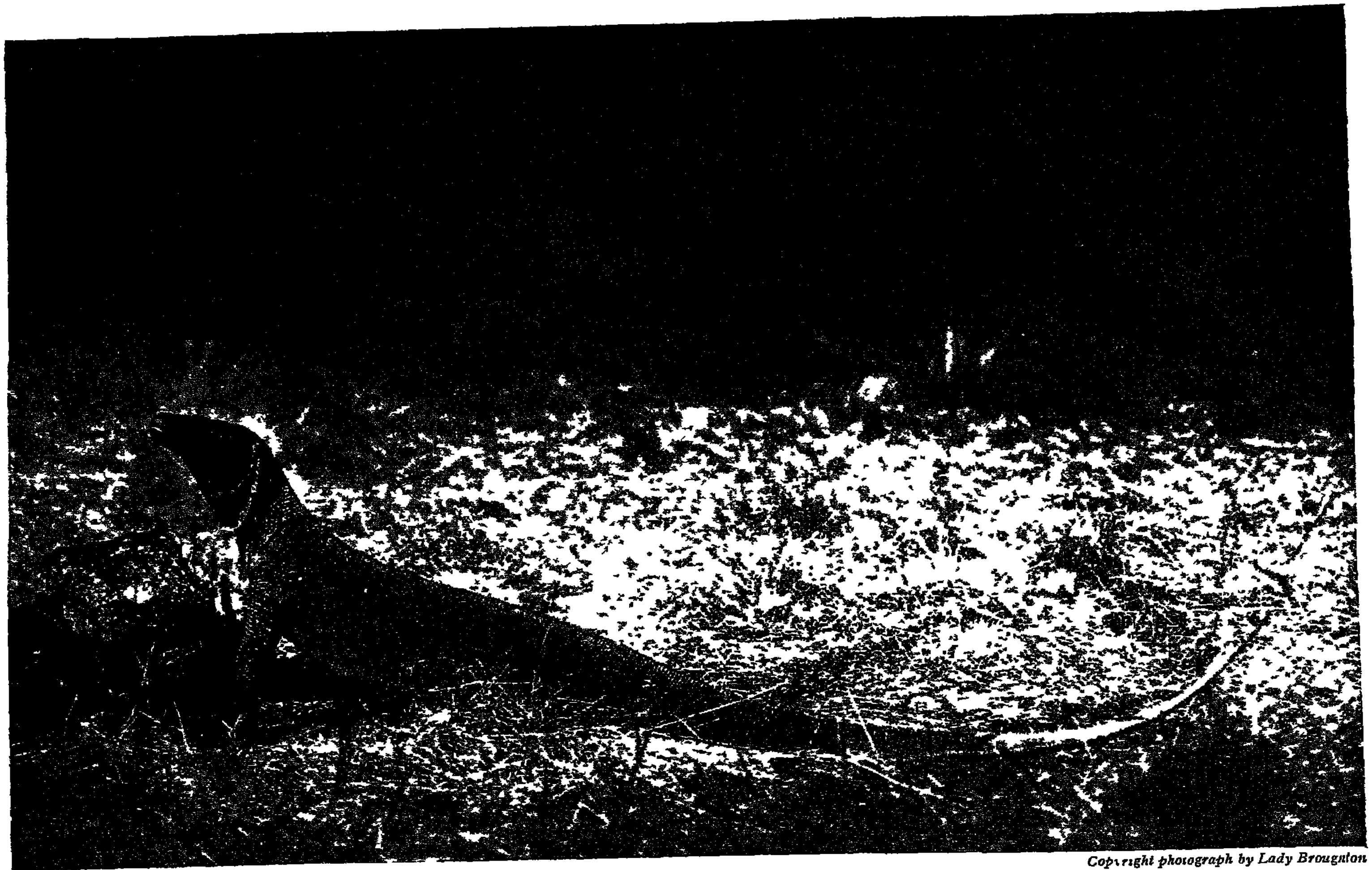
So implicit was the belief in dragons that even scholars and naturalists of the gravest cast of mind were not above giving elaborate descriptions of these monsters, in company with their dissertations upon the other members of the animal creation. All such descriptions were but variations on the characteristic snake or lizard shape; and it may well be that the dragon legend was perpetuated so long and so faithfully by the periodical discovery of the fossilized remains of gigantic lizards that walked the earth in prehistoric times. These huge saurians, some of which attained a length of more than twenty feet, must have been truly terrifying beasts; and a further suggestion may not be entirely worthless: namely, that living specimens of these great reptiles which had survived long enough to be observed by more or less intelligent human beings might conceivably have been the prototypes of the traditional dragon.

To-day the race of dragons has sadly degenerated. Nature can still produce almost the exact image of the dragon or giant saurian of old, so far as concerns appearance, repulsiveness and relative ferocity; but in the matter of size her wonted powers have deserted her, and the largest "dragon" that is known to exist scarcely exceeds fifteen feet in length. In some respects it can be regarded as a new dragon, having become known to civilization only within recent years, yet there is small hope of its ever being ousted by any larger species from its proud position of modern heir to all the dragons of antiquity.

The Dragons of Komodo

The strange creature to which we are referring is the Komodo Dragon, which hails from the small island of Komodo, in the Malay Archipelago. A heavy, ungainly animal, dull and earthy in hue, with its loose skin hanging in folds, this quaint "dragon" looks indeed like a fantastic creature from another world, as it prowls about with its long tail trailing behind it, its forked tongue flicking in and out, and with now an expression of intense ferocity, now an ugly yet comical smirk, upon its scaly face. The existence of this giant lizard had long been a tradition among the Malays, yet it was scoffed at by European naturalists until the finding of the first specimens, in 1912. Now the Komodo Dragon is to be seen in many zoological gardens; a fine pair was presented to the London Zoo in 1935.

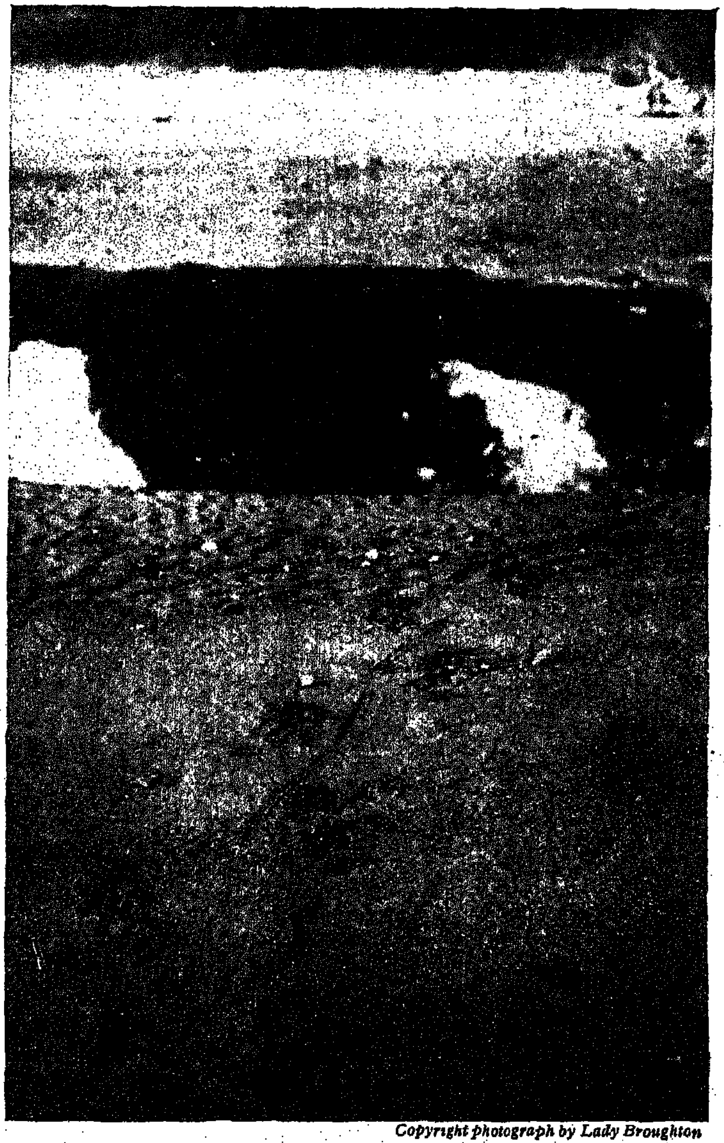
The Komodo Dragon belongs to a family of large lizards known as Monitors, this name being derived from the fact that they are popularly supposed to give warning of the



Copyright photograph by Lady Broughton

Possibly a descendant of the fiery monster of legend and story, certainly a beast of fearsome size and appearance—a 12 ft. Komodo Dragon at home. This unique photograph was secured on the island in the Malay Archipelago where the dragon lives and from which it takes its name

approach of crocodiles, their hereditary foes, by making a hissing sound. The Monitors are powerful creatures, with strongly developed necks, long, slender, forked tongues, long tails furnished with a low ridge or crest, and powerful feet and claws; and they are covered all over with very small scales. One of the commonest of these great lizards is the Monitor of the Nile, which is of an olive-grey colour, mottled with black. This Monitor is an agile swimmer and feeds largely upon the eggs and young of crocodiles; and, being itself an inoffensive creature, it is of great value in districts infested with these beasts. It reaches a length of five or six feet. Equally at home in the water is a seven-foot Monitor from south-eastern Asia, which, previous to the discovery of the Komodo Dragon, was regarded as the largest of living lizards. When alarmed in the branches of trees, this Monitor is said to plunge from a considerable height into the water beneath.



Copyright photograph by Lady Broughton

Evidence that the dragon had called for a drink—the monster's curious "spoor" and wavy tail tracks. A photograph taken on the island of Komodo

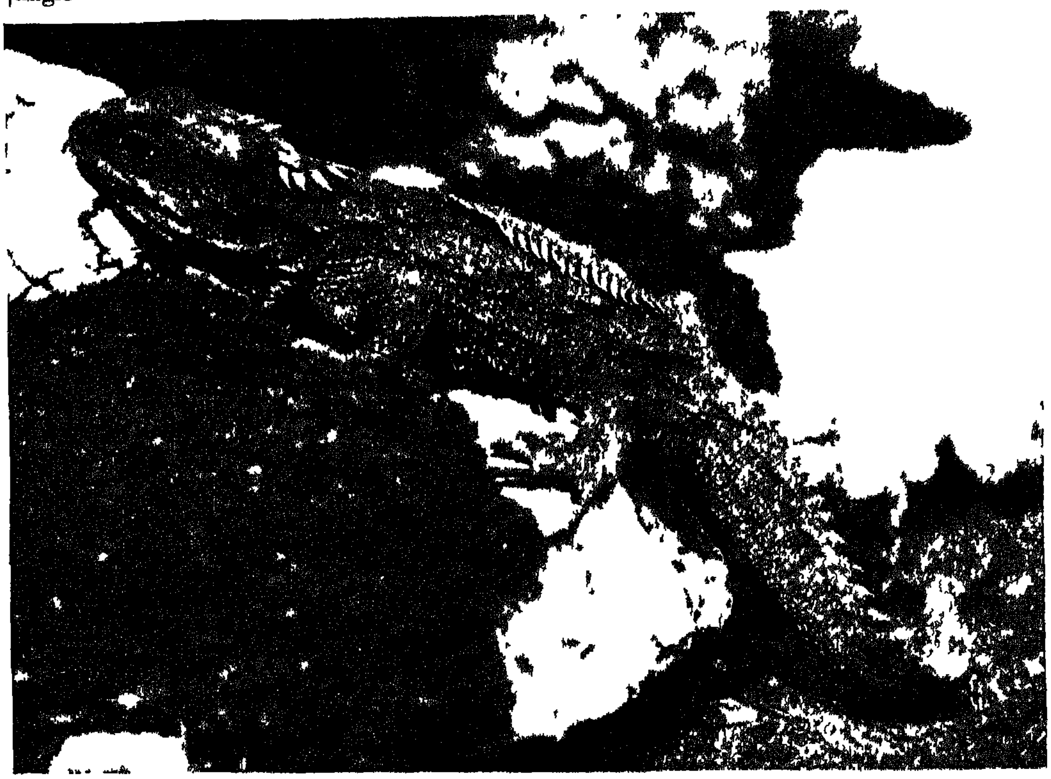
The great strength and agility shared by all Monitors is, in an Indian species, put to a strange but well-attested use by thieves and burglars. The Monitor in question is about five feet in length, and is celebrated for its ability to climb walls. The intending housebreaker liberates one of these useful beasts at the scene of his operations, and the Monitor, in endeavouring to escape over the wall, drags up the man after it, clinging to its broad, strong tail.

In India there is popular belief that the bite of a *young* Monitor is more deadly than that of any snake. However, this idea is quite erroneous, and all the Monitors are quite inoffensive to man at every stage of their life; even the formidable-looking Komodo Dragon, king of all lizards, is an object of wonderment, not of fear. In India, Burma and Ceylon, many species of Monitor are a favourite article of food among the natives, being esteemed a great delicacy; and their eggs, which are usually deposited in the ground, or in a deserted white ants' nest, are eagerly sought for.

Another modern monster—though a dwarf beside the Monitors—is the Great Dragon of Guiana and other parts of tropical America. This is a strong, active and determined animal, with splendid powers of running and climbing. It measures between four feet and

six feet in length, and in colour is olive green, mottled with brown, with a yellow belly. This lizard, too, is hunted for its flesh and eggs, but when it has turned at bay in its deep burrow it is an opponent to be reckoned with, and the ferocious snaps of its powerful jaws can inflict a very painful wound.

Most dragon-like in form of all the lizards, and yet very small and inoffensive, are the aptly-named Flying Dragon of the forests and jungles of southern Asia These very strange opened and closed with a pretty, fluttering movement, the charm of which is enhanced by their brilliant colouring. But when the lizard wishes to remove to a neighbouring branch or tree, it spreads its parachute, launches itself boldly into the air, and swoops rapidly from bough to bough, alighting every time upon its objective with unerring precision. There are about a score of species of flying dragons, distributed through India, Java, Borneo, Malaya and the Philippines,



The Tuatera Lizard is said to approach more nearly in structure to the prehistoric reptiles than any other animal living to-day. A native of New Zealand, it is itself almost extinct

yet graceful little creatures are only about ten inches in length, and of this the long and slender tail comprises the greater part. Their chief claim to distinction, and the attribute which puts them in the rank of "dragons," is the broad, wing-like expanse of skin growing out from each side of the body and supported on long, bony ribs like those of an umbrella, by means of which these curious appendages can be opened or folded at will.

The Flying Dragons spend their lives in the tree-tops, and when running about the branches in search of insects, these "wings" are kept tightly folded by their sides, though every now and then they may be rapidly and all attractively coloured and inoffensive creatures. In Sumatra is found the fringed flying dragon, whose back and wings are ornamented with black spots, each within a white ring; its long tail is very slender and whip-like, and is covered with sharp, keeled scales.

Among the interesting lizards of Australia, two must be singled out which are so remarkable and so forbidding in appearance that had they been built upon a larger scale they would have seemed like the blood-chilling phantoms of a nightmare. The first of these creatures, the frilled lizard of Queensland, is normally a sober, yellow-brown, harmless-looking animal, attaining a length of about

three feet and presenting no features out of the ordinary. But when it is angry or alarmed, it has the power of suddenly erecting a capacious, multi-coloured frill of skin, which stands out stiffly, like an enormous ruff or collar, all round its neck. At the same time the lizard assumes an expression of intense ferocity, opens its mouth and gives voice to a loud hiss. It has the equally curious habit, when agitated or alarmed, of rising upon its hind legs, like some of the giant prehistoric lizards, and running along in this semi-human pose, with its fore-feet held like arms. When going quietly about its own business, it runs like other lizards on all four legs, and its frill is folded neatly over its shoulders in pleats. But when the frilled lizard stands at bay, it looks so terrifying that even the boldest dogs, it is said, will turn away from it.

The frilled lizard's rival in fearsomeness is the Moloch, which zoologists have aptly christened *Moloch horridus*, for in regard to appearance this truly fantastic and repulsive lizard fulfils all the qualifications that were expected of the dragons of ancient legend; its only shortcomings are that it does not breathe out fire, and is barely more than ten inches or so in length. From its blunt nose to the tip of its tail the Moloch is literally covered with sharp, upstanding spikes and tubercles. Two very large curved spines spring from the top of its small head, while another projects from each of its eyebrows. On the back of its neck it bears a prominent hump crowded with spikes, while its back is covered with strong, sharp spines, each of which is surrounded by a circle of smaller ones. The spaces between are covered with hard, warty excrescences, extending as far as its powerful claws, while the Moloch's short tail is also heavily armoured with spikes arranged in whorls, so that it looks like the most deadly battle-flail imaginable.

Yet this grim and terrifying appearance is but a mask to conceal a timid and inoffensive disposition, for the Moloch has no offensive weapons and cannot run very fast, so that without its fearful armature and ferocious expression it would be very quickly exterminated by its foes. As it is, any animal rash enough to seize the Moloch in its mouth needs little inducement to drop its prickly burden.

Courtesy of the British Museum (Natural History)

Bristling with sharp spikes, the Moloch, or Thorny Devil of Southern Australia, is a most repulsive looking creature. Its looks belie it, however, for the Moloch is quite harmless and lives chiefly on ants. It is here shown about half natural size

As though in doubt whether its appearance be sufficiently formidable, the Moloch has another "card up its sleeve," for it is capable of bewildering changes of colour. Normally of an inconspicuous yellow hue, spotted with brown, it grows darker under the influence of fear or anger and then changes to a livid grey suffused with red, a feat by which its appearance of malignancy is considerably increased.

Among the interesting family of lizards known as Iguanas are many that attain a large size. The common Iguana, for instance, which is a native of tropical America and the West Indies, reaches a length of six feet, and is a heavy, bulky animal, green in colour with

a mottling of brown, grey and blue. Its under-parts are a light yellow-green, and suspended beneath its throat is a large, loose bag of skin which is partly extended when the animal is excited or enraged. Though really quite harmless and inoffensive creatures, these large Iguanas have a markedly forbidding and dragon-like appearance, due not only to their size but chiefly to the long, erect crest, resembling a row of sharp spines or teeth, which runs from the nape of the neck to the very extremity of the Iguana's tail. The throat-pouch, too, has a row of indentations along its fore-edge.

The Iguana is a timid, indolent animal, spending the greater part of its life high up in the tree-tops overhanging tropical rivers and swamps, where it browses on the shoots and leaves and where its greenish coloration makes it very inconspicuous. When seriously alarmed, this bulky lizard tumbles headlong into the water beneath, even from the loftiest trees, and remains submerged for an hour or more until it considers the danger to be past. The flesh of some of the Iguanas, like that of the Monitors, is considered very good eating by the natives, who track the lizard to its burrow with dogs, or simply capture it with a noose while it is resting.

Sea Lizards of the Galapagos

Many of the Iguanas will take readily to fresh water, swimming with strokes of their long, flattened tails. But in the Galapagos Islands, in the eastern Pacific, there is a species of Iguana which swims freely in the sea, being the only existing lizard that is known to do so. These remarkable reptiles are about five feet in length when fully grown, and are of a dirty-black colour and intensely ugly, with a blunt nose, a crest of spines along the back, and a fierce expression. In the breeding season, however, these marine lizards are covered with large blotches of green, which flash brilliantly in the sun like enamel. At this time the head becomes pure white. The long, compressed tail forms a perfect swimming organ, and the middle toes are connected by a strong web.

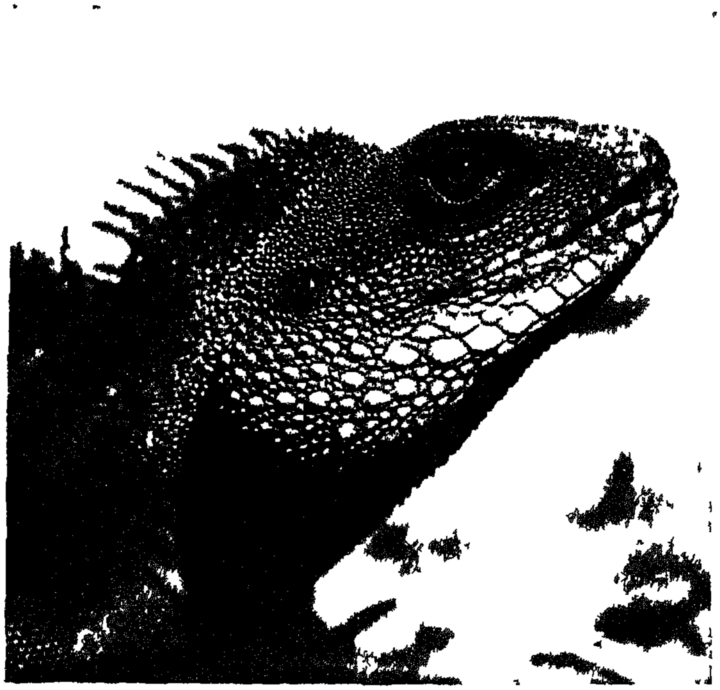
Though repellent in appearance and armed with sharp, powerful teeth, the sea lizards are harmless in their habits and feed entirely on seaweed. They may be seen basking in the sun in enormous numbers along the shore of

H. J. Shepstone

Handsome and dignified despite its fringe of spikes—an Iguana from the forests of the Amazon. These big lizards are usually green in colour, with brown bars or bands, which makes it difficult to distinguish them from the foliage wherein they spend most of their time

various islands of the group, and they do not seem to feel the slightest fear of man. The herds of these lizards are so vast, covering up to three acres, that when they are all crawling along at once, it has been said, the very ground seems to be in motion. They enter the sea in large numbers, and may be observed swimming about together some hundreds of yards from the shore; and when on land they will not stray as much as ten yards from the water's edge.

Charles Darwin, who visited the Galapagos Islands during the voyage of the *Beagle*, came to the conclusion that marine Iguanas fed largely upon a kind of seaweed which grew only at the bottom of the sea, some distance from land, which would seem to show considerable powers of diving on the part of these lizards. At all events, they can remain submerged for a very long time without harm· "A seaman on board sank one," says Darwin, "with a heavy weight attached to it, thinking thus to kill it directly; but when an hour afterwards he drew up the line, the lizard was quite active."



Showing the concentric pattern of scales round the eye and the spiny crest at the back of the neck—*the head of a Cochin China Water Lizard*

Charles Darwin's Experiment

But, though this Iguana is such a thoroughly aquatic creature, it presents, observes Darwin, one strange anomaly, "namely, that when frightened it will not enter the water. From this cause, it is easy to drive these lizards down to any little point overhanging the sea, where they will sooner allow a person to catch hold of their tails than jump into the water. They do not seem to have any notion of biting; but when much frightened they squirt a drop of fluid from each nostril. One day I carried one to a deep pool left by the retiring tide, and threw it in several times as far as I was able. It invariably returned in a direct line to the spot where I stood. It swam near the bottom, with a very graceful and rapid movement, and occasionally aided itself over the uneven ground with its feet. As soon as it arrived near the edge, but still being under water, it tried to conceal itself in the tufts of seaweed, or it entered some crevice. As soon as it thought the danger was past, it crawled out on the dry rocks and shuffled away as quickly as it could. I several times caught this same lizard by driving it down to a point, and though possessed of such perfect powers of diving and swimming, nothing would induce it to enter the water; and as often as I threw it in, it returned in the manner previously described. Perhaps this singular piece of apparent stupidity may be accounted for by the circumstance that this reptile has no enemy whatever on shore, whereas at sea it must often fall a prey to the numerous sharks. Hence, probably urged by a fixed and hereditary instinct that the shore is its place of safety whatever the emergency may be, it there takes refuge."

In the centre islands of the Galapagos group is found another Iguana, a land-dweller and somewhat smaller than its brother of the sea. Though fierce in expression and intensely ugly, it yet can boast a respectable coloration, having a red body and bright yellow head and feet. It is quite harmless, feeding on cactus and succulent leaves and berries, and often climbing trees to browse amid the branches; but when seriously annoyed, this Iguana can bite savagely.

These lizards are becoming sadly depleted as a result of the depredations of wild dogs, descended from those brought to the islands by early settlers; though when Darwin visited the Galapagos group in the 1830's they were exceedingly numerous. "I cannot give a more forcible proof of their numbers," he relates, "than by stating that when we were left at James Island we could not for some time find a spot free from their burrows on which to pitch our tent. . . . When walking over one of these lizard warrens, the soil is constantly giving way, much to annoyance of the tired pedestrian. . . . I watched one [burrowing] for a long time, till half of its body was buried; I then walked up and pulled it by the tail; at this it was greatly astonished, and soon shuffled up to see what was the matter; and then stared me in the face, as much as to say, 'What made you pull my tail?' . . . They are not at all timorous; when attentively watching anyone they curl up their tails and, raising themselves on their front legs, nod their heads vertically with a quick movement and try to look very fierce, but in reality they are not at all so; if one just stamps the ground, down go their tails and off they shuffle as quickly as they can."

Photo: New York Zoological Society

The agile Land Iguana of the Galapagos Islands, though provided with a formidable set of claws and an unprepossessing appearance, is as inoffensive as its sleepy look here suggests

Strange Legends of the Basilisk

Related to the Iguanas is the curious Basilisk, which is notable for its striking appearance even among the lizards, in the creation of which Nature has made so many fantastic experiments of habit, form and colouring. In earlier and more credulous days, the Basilisk was a fearsome beast of myth and legend whose very glance had the power to slay those upon whom it rested. "Come, basilisk, and kill the innocent gazer with thy sight," Shakespeare makes Henry VI say to the Earl of Suffolk. Visualized as a scaly, lizard-like creature with eight legs, a cruel beak and red, fiery eyes, it was popularly believed to spring from an egg laid by an aged cock and hatched by a toad or serpent.

As its name signifies, the Basilisk was regarded as the king of reptiles, and in ancient books it is depicted with a royal crown upon its head. "He seemeth to be the Kinge of Serpents," naïvely observes a medieval author, "because of his stately face and magnanimous minde." The very flesh fell from the bones of any unfortunate creature that encountered a Basilisk, and all vegetation was laid waste by its fiery breath. Men could contend with the Basilisk—though at the greatest peril—only if armed with a mirror which turned its fiery gaze upon itself. The only living creature that could oppose it on equal terms was the cock, and this brave bird would even appear at times to have got the better of the "Kinge of Serpents," who fled away incontinently into the desert at the sound of the cock's raucous voice. Hence travellers through desert regions, where the Basilisk was most to be

feared, were gravely advised by ancient writers to carry with them a number of shrill-voiced cocks. According to other authorities, it was the weasel alone that could contend with the Basilisk, and then only by giving itself a fresh lease of life and strength during the struggle by eating rue.

In striking contrast to its mythical forebear, the lizard that is known to modern zoologists as the Basilisk is a shy, inoffensive little creature, that only in its quaint appearance displays any resemblance to the "Kinge of Serpents." A native of Martinique, Guiana and other parts of tropical America, the Basilisk is between two feet and three feet in length, and is very attractively clad in green and brown, with shades of blue on its back, beneath, it is a silvery white Its most remarkable feature is a kind of bag, shaped like a pointed hood, which it bears upon the top of its head and can erect at will Along its back, too, there is a high crest, supported, like the dorsal fin of a fish, upon long, spine-like processes and capable of being erected under the influence of irritation or emotion. The long tail of the Basilisk does not taper gradually from the body, as is the case with the majority of lizards, but leaves the animal's hindquarters abruptly, as though it had been attached as an afterthought. It is provided with a separate and distinct crest of its own, which is movable like that on the back, and the tail is so attenuated towards the end that the joints of the vertebræ show distinctly through the skin that covers them

The head of the Basilisk is small and narrow, with a pointed snout, and it has an inexpressibly knowing appearance as it suns itself on the boughs of trees in its native forest, or browses on the luxuriant vegetation. When alarmed, it plunges into the water below, though except in moments of danger it does not readily take to swimming. The Basilisk does not swim with strokes of its tail, like other Iguanas, but *allows it to trail* inertly behind it, and sitting almost upright in the water propels itself along with its hind legs.

In the dry desert regions of North America, ranging from California to Texas and Mexico, are found the fantastic "horned toads," which, this popular name notwithstanding, are in reality lizards, related to the Iguanas. In appearance these creatures are indeed rather toad-like, being broad and squat, with *a short, wedge-shaped tail, compared with* the long, tapering tail of most other lizards. Living in dry, sandy or stony districts, where there is little cover, they are protectively coloured in grey and brown to match the hues of the earth; and further, are almost entirely covered with large spiny scales, though not so lavishly as is the Moloch of Australia.

The "horned toads" are quite harmless to

Photo Dr Weller

The Giant Zonure, or Great Girdled Lizard of South Africa, is found chiefly in Basutoland and the Orange Free State. About 15 ins. in length, it is covered with an armour of sharp pointed scales

man and other animals and feed entirely upon red ants, beetles and other insects, running rapidly over the sun-baked earth in their quest for them. In captivity, however, they are sulky and sluggish, and often will resolutely refuse to move or exhibit the slightest sign of life, even if pushed or irritated.

"Toads" that Squirt "Blood"

These curious lizards have the habit of burrowing a little way into the sand to conceal themselves from their enemies, while the sharp, backwardly-directed spikes on the head prevent them from being devoured by snakes and other predatory foes. But the most remarkable weapon in their armoury consists of the well-attested power of being *able to squirt a fine jet of fluid—coloured red* like blood—from the corner of their eyes full into the face of an aggressor.

We cannot conclude our story of modern dragons and monsters without some account of the large serpents with which, probably, most dragon-fables originated. In Babylonia, in ancient India and in the America of the Aztecs, snake worship played a prominent part in the national religion; and even among the Greeks and Romans, serpents were held in great honour and esteem for their supposed wisdom and benign powers. And large serpents, probably of the python kind, have helped to inspire at least one masterpiece among the world's heritage of great art—the celebrated sculptured group of the Laocoön.

Formerly all large and non-poisonous snakes which depend upon the crushing power of their muscles for killing their prey were ranked together as Boas; but among modern zoologists this term is usually restricted to a particular division of large snakes of which the majority are natives of America, although many species are found in the hotter parts of the Old World, from North Africa to Madagascar and New Guinea. It is an interesting sidelight on their evolution to note that all Boas possess unmistakable traces of pelvic bones and even of hind legs, the latter being represented by a pair of rudimentary claw-like spurs, placed one on either side of the vent; it is probable that these appendages assist their owner to some extent in climbing trees, by their friction against the bark.

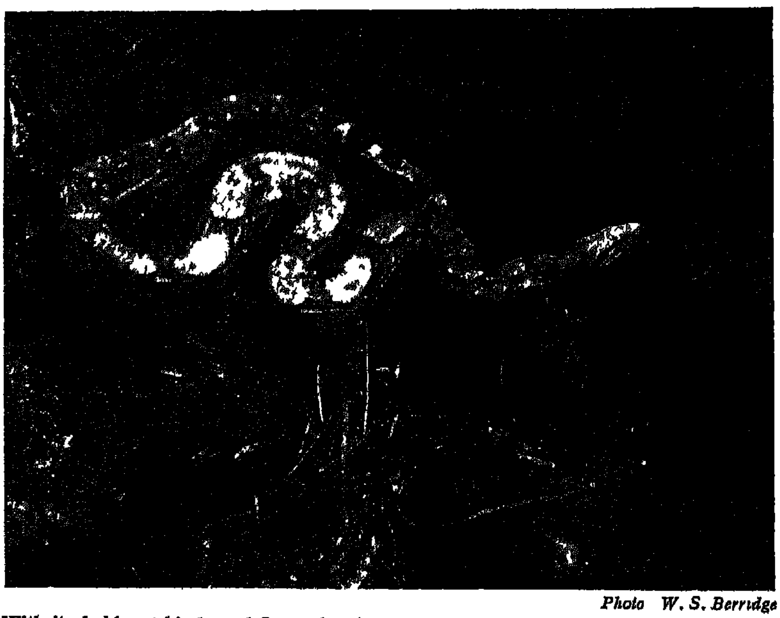


Photo W. S. Berridge

With its bold markings and fine colouring, the Boa-constrictor is beautiful enough to look at, and its patterned skin is seen to good advantage when distended after a meal (*top*)

The Boa-constrictor, the species most familiar, in name at least, to the generality of people, is a native of the forests of tropical America, from Mexico to Brazil and Paraguay. It is a splendidly coloured snake; the prevailing tone is a rich brown, and along the back extends a row of large, pale patches, oval in form, with the ends cut away in a half-moon shape. The tail of the Boa is more brightly and boldly ornamented than the remainder of its body, approaching a dark red hue, with black and yellow splotches. The sides are adorned with large diamonds and bars of brown, while the under-parts of this fine snake are of pale yellow, spotted with black.

Despite the popular belief in the excessive size attained by the Boa-constrictor, it would appear that a length of twelve feet is the

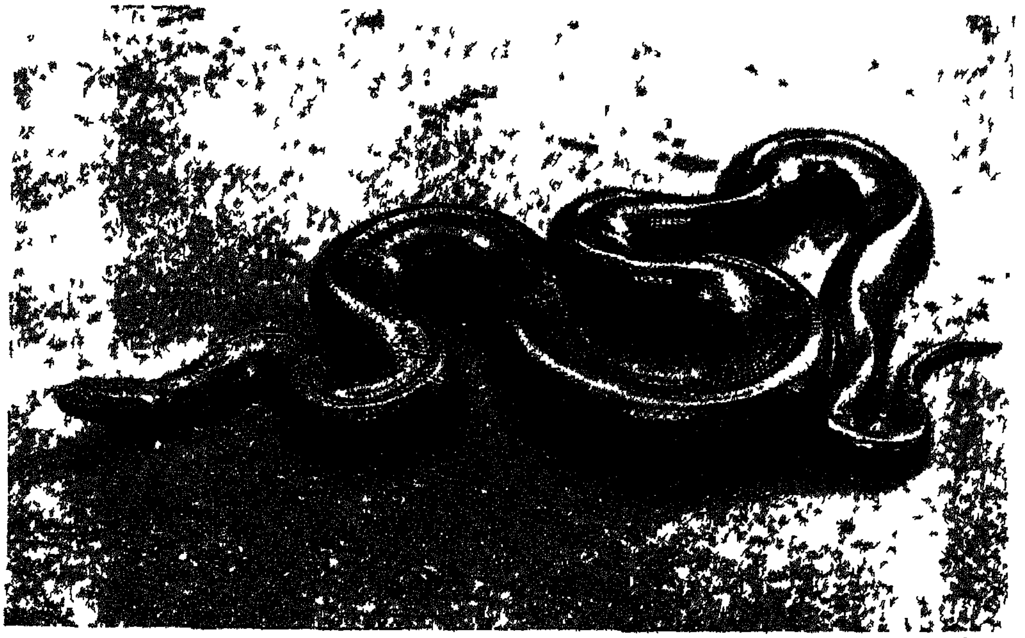
maximum for this snake Its ferocity, too, seems to have been greatly exaggerated, and according to all authoritative reports, it is shy and inoffensive in its attitude towards man The natives of tropical America have long been accustomed to keep the Boa as a domestic pet in their cabins, where it lies sluggishly during the day, awaking as evening approaches to hunt the rats that swarm everywhere.

How the Boa seizes its Prey

The Boa's method of seizing its prey is swift and fatal. A lightning snap of its widely opened jaws serves to secure the victim, and almost instantaneously a fold of the serpent's body, near the head, is thrown round the struggling animal, being reinforced by others in swift succession One after the other, the bones of the victim are broken by these living coils of steely muscle, and then begins a process of swallowing which, if the prey is bulky, is likely to prove a long and fatiguing one. After a heavy meal the Boa may remain torpid and quiescent for a considerable time while digestion is in progress, and on re-awakening it is usually extremely hungry, specimens in captivity being known at this time to swallow their bedding, litter, and other foreign bodies in order to appease their ravenous appetite.

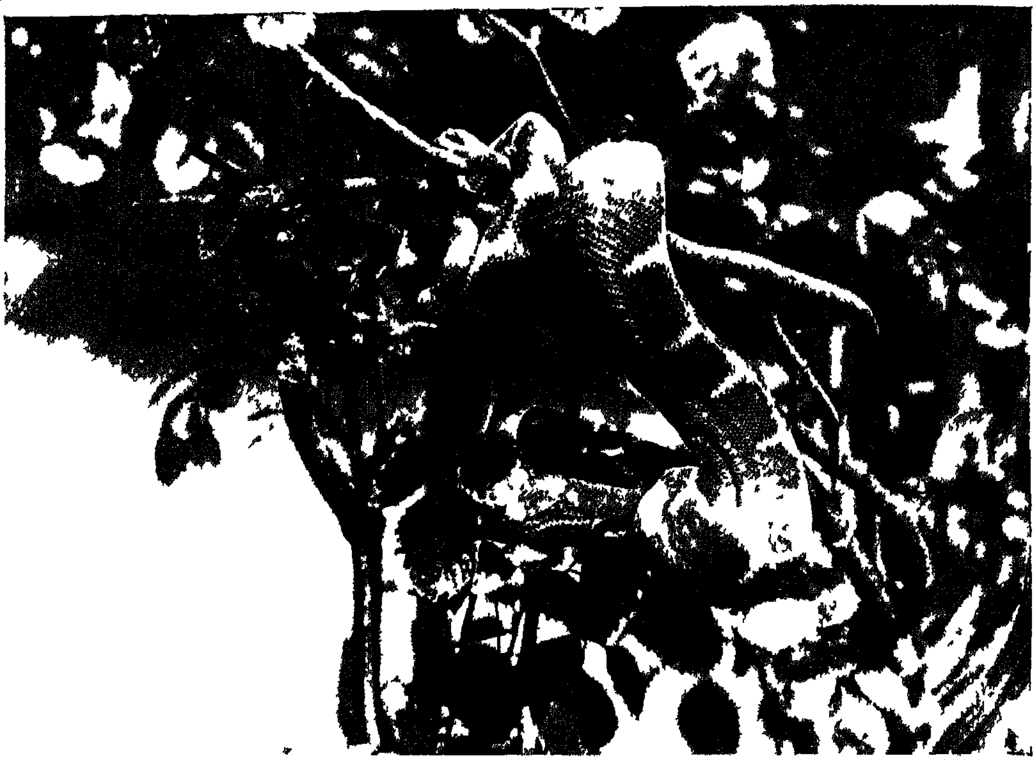
A near relative of the Boa is the Anaconda, of South America, which spends a great part of its time in rivers and pools, and so has been modified for an aquatic life by the possession *of very capacious lungs and the ability to* close the nostrils entirely, so that no water can enter. The Anaconda is a large snake, reaching a length of thirty or even thirty-five feet, and thick in proportion Like the Boa, it is non-venomous, relying upon the terrible crushing power of its coils to kill its prey; but, unlike the Boa, it is said to have a ferocious temper, although, so far as is known, it does not attack man To do the Anaconda justice, it is a remarkably handsome creature; on a ground colour of rich olive brown it has two rows of large oval, black spots laid in alternate order along its back, while its sides are marked with light golden-yellow rings, each of which is fringed with black and has a conspicuous white eye in its centre The pale belly is spotted with black, and bears two spur-like, rudimentary hind limbs.

In the rivers of tropical South America the Anaconda may be seen swimming along *swiftly like an eel, with a rapid, sinuous* movement of its body. When lying in wait for its prey, which it does chiefly at night, it submerges itself in the water near the bank, with only its nostrils showing ab[illegible] surface, and the Indians take [illegible]



Courtesy of the Booth Mus

Disposed in true serpentine coils—an Anaconda from the Amazon. This immensely powerful snake often attains a length of over 30 ft., and kills its prey by crushing



H. J. Shepstone

The Python usually lies in wait for its victim, coiled firmly among the branches of a tree. Like the Boa-constrictor and Anaconda, it squeezes its prey to death and then swallows it whole

cautions against its presence in the water before venturing to bathe. When any unsuspecting creature comes down to drink, the Anaconda darts swiftly from ambush and seizes it by the nose, dragging it beneath the water and enveloping it in its crushing folds. Its victims are usually tapirs, otters, agoutis, ant-eaters, iguanas or birds; but stories of its swallowing large deer, horns and all, seem to rest on a very slender foundation, although it is but fair to remark that a naturalist of no less repute than Alfred Russel Wallace states explicitly (in his "Travels on the Amazon") that "it is an undisputed fact that they devour cattle and horses." This great snake frequently deserts the water for the branches of trees, where it noiselessly awaits its prey, but on the ground it is comparatively clumsy and helpless, and may then be killed fairly easily. Its fat yields a fine oil which long enjoyed a reputation for the cure of sprains and rheumatism; six gallons or more are said to be obtainable from a single specimen. The Anaconda's hide, like that of Boas, is made into a very tough and handsome leather.

The Pythons, which in point of size are the only rivals of the Anacondas, are essentially snakes of the Old World, where they are common throughout the tropics, even in Australia. The netted, or reticulated, Python of Burma, Siam and the Malay Archipelago, and the Indian Python, or rock snake, are the largest species, with a length sometimes of thirty feet, but it is very usual for any but scientific observers to exaggerate the size of pythons to the point of absurdity, a length of forty or sixty feet being commonly vouched for. Stories of pythons swallowing excessively large animals should be received with great reserve, since the jaws of even the largest specimens, although capable of being enormously extended, could only with difficulty cope with any prey larger than a sheep or goat.

Habits of the Python

The body of the Python is large, round and sinuous and immensely strong, and is covered with a broken, irregular network of markings in black and various shades of brown. The tail is prehensile, and rudimentary hind limbs exist, as in the Boa and Anaconda. Besides being a powerful swimmer, the Python is very

active on land, but it prefers to lie in wait for its prey in the boughs of trees overhanging rivers and water-holes, where it is very inconspicuous among the dark foliage. Seizing its victim suddenly, it crushes it to death, reducing it to a sausage shape before swallowing it. If the prey be large, the operation of swallowing is apt to be very laborious and protracted, even though facilitated by the secretion of an enormous quantity of saliva with which the Python's prey is liberally covered. The common impression that the dead animal is anointed with saliva before the Python begins to devour it is quite erroneous.

The Python is the only snake that seems to show any solicitude for its eggs or young. The female Python wraps herself, fold upon fold, around her heap of eggs, which number seven or eight dozen, and guards them jealously. A high temperature is generated within this natural incubator, and the eggs hatch in a period of between two and three months. The mother Python will not forsake her trust for a single instant, and goes entirely without food during the whole of this time.

Apart from such works as the Laocoön group, already mentioned, there are many indications of the awe inspired by serpents of old. The Python of mythology was a serpent or dragon born of mud left after the deluge with which Zeus overwhelmed the world. The great serpent, according to legend, was slain at Delphi by Apollo.

Photo: Dr. Graf Zedlwitz

Like the rest of its tribe, the handsome Sand Viper is highly poisonous. It is found in Southern Europe and feeds on small animals

When angry, the Green Whip Snake of Southern Asia inflates its neck; it lives in trees and though very thin is of tremendous length

CHAPTER XVI
THE ROAD BUILDERS

ALL through the ages roads have exercised the greatest influence on civilization. They have been the first step towards commerce and towards social and national intercourse; for wherever lines of communication are established between men, commerce follows, and with commerce comes civilization.

Man's first roads were merely trails; they approximated to the tracks made by wild beasts that leave their lairs at night to slake their thirst at a jungle pool. The first trails of man, too, were probably ones that led to streams or water-holes. Later he travelled farther afield, hunting and fishing; and also in quest of richer soil for cultivation and fresh pastures for his beasts. He encountered other tribes, fraternized and fought, and whether the former or the latter, added to his store of knowledge both topographical and general. Man soon found that peaceful intercourse with his neighbours brought him considerable benefits, and there sprang up a system of barter or trade which later became less localized and spread along trails and tracks and roads from one corner of the land to the other.

Amber Roads of Central Europe

These trading routes, which stretched over long distances, existed long before the dawn of history; the earliest of which we have any knowledge are the amber roads of Central Europe. Amber is a resin discharged long ages ago by coniferous trees and fossilized; it was much in demand by the ancients because of its supposed medicinal or magical properties. When ground into a powder and mixed with rose-oil it formed a paste which, if taken internally, was believed to cure deafness; a similar paste made with ground amber and honey improved the sight, so it was thought; and a necklace of amber was a cure for ague. Children often wore it as an amulet, since as a charm it was considered unrivalled. It was used for many other purposes, some useful, some merely ornamental; and man's desire to possess it led to the establishment of trade roads from southern Denmark, through eastern Prussia, down to the Mediterranean. The general route lay via Hamburg, Magdeburg, Dresden, Passau, Brenner, Verona, and the main towns of Italy; but another route led from Magdeburg through Mainz to Basel in Switzerland; and still another road led from Danzig in an almost straight line to Trieste on the Adriatic. Evidence that these were the old amber trade routes is provided by the collections of amber found in the graves of the folk of the Early Iron and the Bronze Ages.

Trade routes also came to be made as a result of the attraction that lapis lazuli held for the Egyptians and Chaldeans. Lapis lazuli is a blue stone of comparative rareness and was obtained from Badakshan in north-east Afghanistan, and from Lake Baikal in Siberia. The exact routes by which lapis lazuli was carried are not known, but that the stone found in Egypt must have originated from the sources mentioned is fairly certain.

Ancient Silk Roads of Asia

The most famous of the old trade routes, however, are the ancient silk roads which traversed central Asia to northern China. The silk industry is wholly of Chinese origin and is believed to have been founded in 2640 B.C. by Si Ling Shi, wife of the Emperor Hwang-ti. For 2,000 years the Chinese jealously guarded the secret of the silkworm, and the method by which they unwound the silk from its cocoon, but eventually the Persians gained this knowledge owing, it is said, to a Chinese princess marrying into Persia; before she left the country of her birth, she hid in her hair some silkworms and the mulberry leaves on which the creatures feed. The Persians for their part cherished the secret, but in order to develop the industry in their country it became necessary to obtain larger supplies of silkworms from China, and thus a trade was established for that purpose between the two countries. The route followed was through the desert of Gobi and the valley of the River Tarim. In the sixth century, silkworms were smuggled out of China by monks, and silk weaving was introduced into Europe.

The main silk routes were: the northern road which crossed Persia and Kashgar to Chinese Turkestan, passing north of the Kuen-Lun Mountains to southern Mongolia and into the valley of the Hwang-Ho; a branch of this road which left Merv in Persia, went south to Afghanistan and through the Khyber Pass into India; and a southern route between Bhamo on the River Irrawaddy

Photo: C. P Skrine

On the ancient northern silk road across Asia along which—in Roman times—the silks of China were brought from the shores of the Yellow Sea to Italy, Gaul and Spain. Caravans still use the road which passes through the village of Yaqa Quduq (seen above), on the southern fringe of the Takla-Makan Desert between Maralbashi and Aqsu

in Burma, through Tengyueh, into southern China. The last-named route extended into India by way of Patna.

The Great Desert Route

The desert trade routes of to-day, with one exception, are closely associated with the ancient roads, since they are not made for vehicular traffic. In Arabia, for example, the same routes which were used in the days of Sennacherib are still utilized by camel caravans to-day. The Great Desert Route lies between Aleppo, not many miles from the Mediterranean, to Basra in the Persian Gulf. For the most part it follows the valley of the Euphrates, and in all is about 770 miles long. A camel caravan takes between twenty-four and twenty-eight days to complete the journey.

The southern half of Arabia has no trade routes, because it consists almost entirely of a waterless desert. In the north, however, in addition to the Great Desert Route there are others along which water is obtainable at natural wells and springs. One such watering-place is Rutba Wells, situated about midway between Damascus and Bagdad. This latter route is the exceptional one mentioned above, for it has proved suitable for motor transport and there is a regular motor-coach service between the two towns. At Rutba Wells is a fortified rest-house equipped with wireless, and Imperial Airways have a base there.

Some pilgrim routes are examples of roads and caravan tracks that came about in another way, though often they were used for commerce in the first instance before taking on their special character. Thus trade of course existed between Mecca and other parts of Arabia before this city became a holy one; during the centuries that followed the traffic grew immensely.

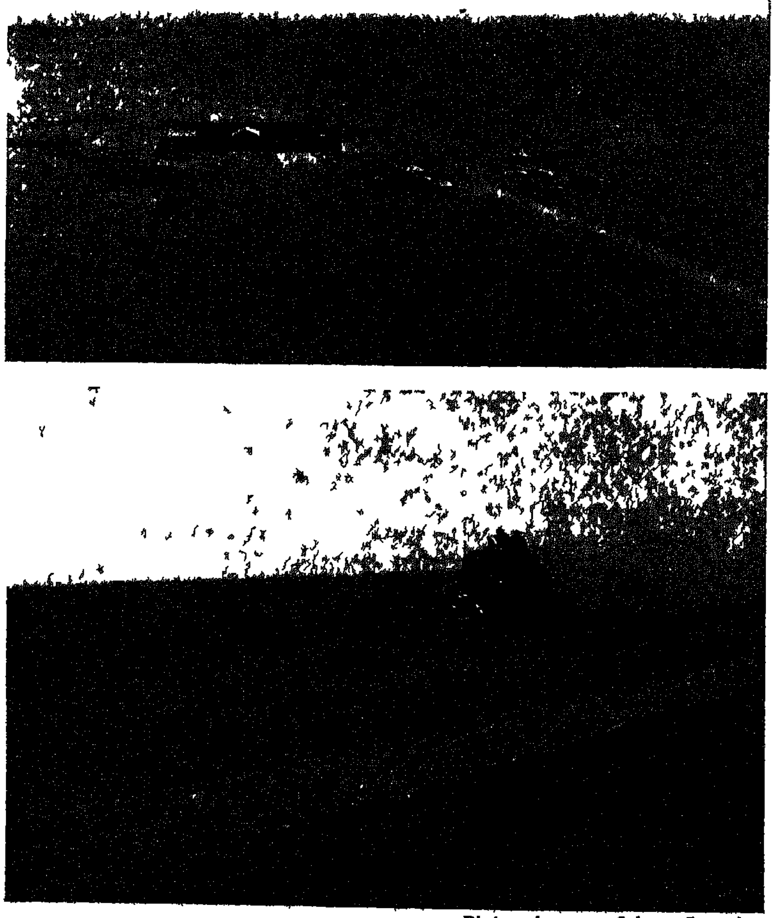
The First Road-builders

The first attempts at making real roads must apparently be credited to the Egyptians, who constructed a solid track for conveying the huge blocks of stone to the site of the Great Pyramid. Herodotus records that "It took ten years' oppression of the people to make the causeway for the conveyance of the stones, a work not much inferior in my judgment to the pyramid itself. This causeway is five furlongs in length, ten fathoms wide, and in height at the highest part eight fathoms. It is built of polished stone and is covered with carvings of animals.

The Carthaginians are said to have had a system of stone-paved roads, in view of the fact that they built up a mighty empire and traded vigorously along the shores of the Mediterranean, and southward into Africa as well as in Spain, it seems more than probable. One historian states definitely that "the Carthaginians were the first that contrived to strengthen, to secure, and to consolidate the roads with stones and flints knit together with sand and, as it were, fastened by masonry on the surface of the earth, which we in one word call paving"

Roman Roads

The Romans, as everyone knows, were great road builders; and Rome built for posterity, as many existing relics of her civilization serve to show. A highly important step in the consolidation or the extension of her empire was the making of a system of roads, for an army cannot travel quickly without them When once a new realm had been conquered, the roads were used entirely for administrative purposes; to aid rapid communication between Rome and her outposts there were built, at distances of five or six miles along the roads, houses at which were stabled forty horses. Thus, all along the route, relays of horses were available for officials needing to travel at the greatest possible speed Julius Cæsar is said on one occasion to have travelled 100 miles in twenty-four hours by chariot, and the Emperor Tiberius to have gone twice as far in a day. As a general rule officials rode on horseback or in light chariots, their luggage accompanying them in heavier vehicles.



Photos American Colony, Jerusalem

Old and new in the desert. Motor transport follows a Roman paved road at Gayara, Iraq. *Top:* A modern caravanserai on an age-old trade route—Rutba Wells, between Damascus and Bagdad, seen from the air

One of the most remarkable features of Roman roads is their straightness. The Romans made no attempt to follow valleys, but in building a road from one town to another they pursued a direct course even if it meant building a bridge across a river or crossing a mountain.

The Road to Constantinople

The most famous of the Roman roads was the Appian Way, which was begun in 312 B.C. When eventually finished it stretched from Rome to Brindisi, a distance of 350 miles; but even there it could scarcely be said to end, for at the seashore two stone pillars marked its debouchment, while on the opposite side of the Adriatic two other pillars marked its continuation into Greece and on to Constantinople. On either side

Photo: Anderson

Most celebrated of all the great roads built by the Romans—the Appian Way outside Rome where it is lined by ruined tombs and other monuments. The great highway was begun by Appius Claudius in 312 B.C.

of the roadway were raised pavements; blocks of stone were set at regular distances in order to assist horsemen to mount, and there were even milestones.

The main road to the north of Rome was the Via Flaminia, which traversed the Apennines to the Adriatic, where it changed its name to the Via Æmilia and continued up the valley of the River Po to Turin. At this point it split up into three mountain roads leading over the Alps; one passed to Grenoble and the Rhône Valley, another went via Verona across the Brenner Pass, and the third road went via Switzerland to Leyden in Holland.

Another road of supreme importance was the Via Aurelia, that passed along the shores of the Mediterranean and up the Rhône to Lyons, where branches radiated across France.

Roman Roads in Britain

The Roman method of building roads was first to cut trenches on either side, the width of the intended roadway. The top surface of loose earth was then removed until a more solid foundation was uncovered, when large flat stones were laid down and set in mortar. On top of this solid foundation looser material, such as smaller stones, rubble and sometimes coarse concrete, was distributed; and on top of that again there was a layer of a finer concrete. Finally large slabs of hard stone jointed together with remarkable accuracy were laid, giving a slightly cambered and enduring road surface. As a rule the roads were about fourteen feet wide with footways seven feet wide on either side. The footways were sometimes paved with stone but more often constructed of pebbles or flint set in mortar, or of hard concrete. The depth of the roadway, including its foundations, was about three feet, unless the road happened to have been built on rock, when the road stones were laid directly on the latter.

The most notable of the Roman roads in Britain was Watling Street, which stretched from Canterbury to Wroxeter, joining up at the Canterbury end with the road to Dover, and at the Wroxeter end with various tributaries to north, south and west Wales. Ermine Street was the Great North Road of Roman times, passing from London to York

via Ware, Royston, Godmanchester, Lincoln and Brough. The Fosse Way connected Lincolnshire with Devon, and the Icknield Way joined the Wiltshire Downs with Branchester in Norfolk.

When Temple Bar was Blocked by Bushes

In England the departure of the Romans brought about the same decay in the roads that all Europe experienced, and not until late in the 13th century do we learn of any attempt to remedy the trouble. In 1285 laws were passed directing that all bushes and trees lining the roads between one market and another should be cut back for 200 feet on either side. Of the repairing of the roads themselves nothing was said. In the 14th century the footpath at the entrance of Temple Bar, London, was so obscured by bushes and thickets that in bad weather it was impassable. Farther west in London the roads were so bad that when the King went to Parliament faggots were thrown into the ruts in King Street, Westminster, before the royal procession could pass that way.

In that same century the first turnpike road came into being (1346), Edward III authorizing a toll to be levied for the repair of roads leading from St. Giles-in-the-Fields to the village of Charing. Similar tolls were authorized for the repair of the road from St. Giles-in-the-Fields down Drury Lane to Temple Bar, and also for that of Gray's Inn Lane.

In the 17th century the stage-coach had made its appearance and the possibilities of longer journeys began to be appreciated. It was a long time, however, before the stage-coach superseded the mounted horseman, the state of the roads being the chief handicap to progress. Along the roads to London could be seen gentlemen, commercial travellers and bagmen, but they never rode singly, for the danger from troops of robbers and vagabonds was as great as ever. Dick Turpin and Bradshaw haunted the Great North Road; Duval, Macheath and Maclean preyed on those who traversed Hounslow Heath, Finchley Common and Shooter's Hill; whilst here and there along the roadside could still be seen gibbets with the remains of one robber or another hanging from them.

The Turnpike Roads

It was the rebellion of 1745 that eventually led the British government to make an effort to improve the roads of this country. The Highlanders, without wagons or luggage of any description, invaded England and travelled nearly half-way to London before any serious attempt could be made to check them. London itself knew nothing of the invasion until many days after the Scots had left Edinburgh, and their mobility put the English army into great difficulties because the bad roads delayed and hampered the cavalry and the artillery. The rebellion, however, was put down and the government immediately gave its mind to improving the roads, both for the purpose of better communication between London, Scotland and other parts of the country, and to enable troops to be moved about the country more rapidly.

The main means of improving the roads was to extend the turnpike system, but at once it met with opposition from the very people who would benefit most by good roads. The road travellers, while they grumbled at the state of the roads, nevertheless were highly incensed at having to pay a tax for passing over roads which had been improved. They wanted the new roads, but they did not want to contribute towards their upkeep. Bodies of armed men moved from place to place destroying the turnpikes and razing the toll-houses to the ground. All along the Great North Road, in Yorkshire and in the outer districts of London, the sternest resistance was put up against the new system. And in districts where there were no riots, the prejudice against the turnpike roads was so strong that the country people would not use them.

Further opposition came when Parliament was petitioned not to extend the turnpike system, but the petition came from the very people who had already benefited by having turnpike roads. Their grounds of complaint were that if the system were spread into remote parts of the country where labour was cheaper, the farmers there would be able to sell their agricultural products at cheaper prices than the farmers nearer London. In spite of all the opposition, however, turnpike legislation went on, and between 1760 and 1774 no less than 452 Acts were passed for making and repairing roads; but the thoroughfares still remained in a very unsatisfactory state, mainly because so little was known about road-making. The old roads were either avoided or else the deep depressions in them were filled up with any type of stone that happened to be handy. The stones were simply thrown in and roughly spread out, and carts and wagons

Photos P L M Collection and (top) E N A

Two famous European road-building achievements: La Corniche, the carriage-road from Nice to Genoa, built by Napoleon—a view at Eze. *Top:* Zig-zag twistings of the road over the Stelvio Pass, Italy, which rises to a height of almost 10,000 feet above sea-level. It is part of the highway from Milan to Innsbruck

left to crush them into some semblance of a road. Any person who desired to take up the trade of road-maker could do so, for it was not considered necessary that such a one should possess any special knowledge

From the many hundreds of mediocre builders who thus set to work there emerged John Metcalf, commonly known as "Blind Jack of Knaresborough," who may be called the first great English road-maker.

John Metcalf was born at Knaresborough in Yorkshire in 1717. He was the son of working people and at six years of age lost his sight following an attack of smallpox. Otherwise he was strong and healthy, learned to play games with boys of his own age, learned to swim and, later, learned to ride a horse. The whole of the district around Knaresborough he knew like a book and, in spite of his blindness, he could find his way anywhere, even on the most dangerous roads. Metcalf grew up to be a man of parts, and in the course of time saved money, bought his own horse, and eventually married. In the rebellion of '45 he enlisted, journeyed through Scotland with the army, and after the English victory at Culloden returned to Yorkshire, where for a time he traded in goods of various kinds between Scotland and his home county.

Metcalf's Life-work

It was in 1765 that Metcalf found his life-work, for in that year an Act was passed authorizing the construction of a turnpike road between Harrogate and Boroughbridge. The surveyor who had to appoint the contractor for the road was in some difficulty, since in that remote part of the country suitable and capable persons for the task were difficult to be found. Metcalf, a shrewd and far-sighted man, realized that if he could make a road satisfactory to the surveyor many of the new thoroughfares which were still to be built might fall to his lot. When he offered to construct three miles of the proposed road between Minskip and Fearnsby the surveyor gladly agreed, and Metcalf sold his trading wagons and started on the new work.

His greatest feat was the construction of the road between Huddersfield and Manchester, which he agreed to make at so much a rood. His tender was submitted before the line of the road had been agreed upon and he discovered eventually that the surveyor had laid it across some deep marshy ground. To dig out the whole bog would have been a tremendously long and costly task. Metcalf protested to the trustees, but they would not give way; he considered the project before presenting himself to them again, this time with the proposal that if they would allow him to construct the road across the bog in his own way he would rebuild it to their plan at his own cost if it proved a failure. This plan was agreed, and as Metcalf had only ten months in which to construct the whole ten-mile stretch, he set to work at once.

Metcalf began by cutting a deep ditch along both sides of the road, throwing the loose earth inwards. Along the boggy part the same procedure was carried out, but heather and ling were pulled up from the bordering ground and bound together into round bundles which were then placed side by side in rows in the direction of the line of the road. Further bundles were then laid across them and the whole pressed well down. Stone and gravel, carried in wagons with broad wheels, were spread over the bundles to make a firm surface, and when the road was completed the section over the bog was as sound and as firm as the rest.

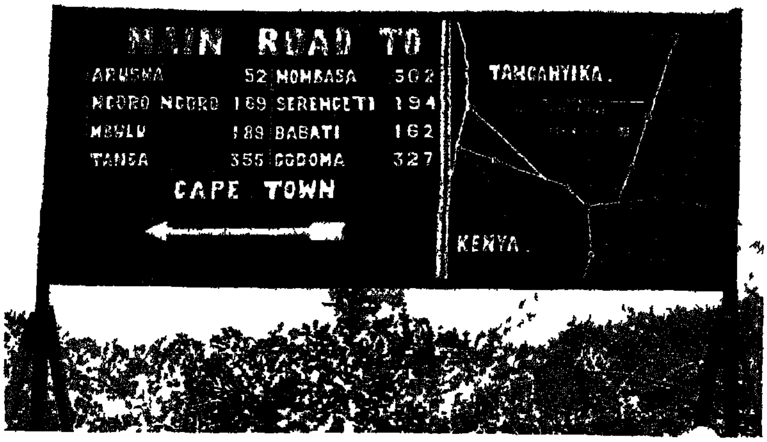
Telford and the Carlisle-Glasgow Road

Another great road engineer in Britain was Thomas Telford, who was born in 1757 at Westerkirk, Scotland. By the time he had grown to manhood the progress of industry and trade and the facilities for travelling rapidly by stage-coach to and from the principal towns in England were very much in the public mind. The roads had certainly been improved but there was still a tendency to allow some of them to fall into decay, and many of them had been so badly constructed that very little laxity in maintenance soon left them in a poor condition. In 1814 a Parliamentary Committee reported that the Carlisle to Glasgow road was in such a bad state that it caused serious delay to the mail-coach and was a source of considerable danger to travellers. The road trustees could do nothing, apparently, and in 1816 an Act of Parliament was passed to reconstruct the road as a national undertaking. Thomas Telford was appointed the engineer in charge, and the road he constructed was sixty-nine miles in length.

In building the road, his first object was to keep it as level as possible in order to assist draught horses; his second, to make the middle of the road as solid and substantial as he could so that it should be able to bear the heaviest weights it would be called on to withstand. In attaining his second object he laid a double "metal" foundation, the lower layer of which consisted of flat stones, seven inches deep, all carefully set by hand with the broadest ends downwards; all crossbonded and jointed, and none of them more than three inches wide on top. The spaces between them were filled up with smaller stones which were wedged in by hand, the whole layer having a perfectly even surface.

Photo American Colony, Jerusalem

Many and serious have been the difficulties encountered by present-day road-builders in outlying parts of the world but, in the main, determination has triumphed and there are now thousands of miles of good roadways where once jungle and forest held sway. Here is a splendid motor-road approaching Nairobi, Kenya Colony, and (*top*) an optimistic signpost on the Tanganyika-Kenya border which really tells the traveller something



The upper course, or layer, was seven inches deep and consisted of whinstones not more than six ounces in weight, and each of such a size that it would pass through a ring two and a half inches in diameter. Over the top layer, gravel to the depth of an inch was laid, and a drain crossed under the bed of the bottom layer at every 100 yards, going to a ditch.

The success of Telford's road led to a great number of others being built. Coach-building had vastly improved, and the comparative ease of travel on the new road stimulated the desire for more rapid communication. All over the country surveys were made and roads laid out, and the rate of travel possible in stage-coaches jumped from five to ton miles an hour.

About the same time that Telford built his first road John McAdam, a retired merchant, became interested in the revival of the roads, owing to the fact that he [illegible]

trustee of a road in Ayrshire. Legislation at the time was tending to be directed at the width of the wheels of road vehicles, and McAdam felt that it was misapplied. In his opinion it was the looseness of road surfaces which was the cause of roads wearing so badly, and not the width of the carriage wheels or the sort of material of which the roads were made. He had come to the conclusion also that a hard, solid foundation was not entirely necessary. He worked out a system for road construction, and when he was later appointed surveyor-general of the British roads he put his method to the test. His system was to use granite, greenstone or basalt and to break it up into sharp angular pieces of approximately the same size. These were merely laid in the road after the bed had been dug to a reasonable depth. Then, while the pieces of stone were being consolidated by the traffic passing over it, the road was carefully watched and any irregularities that showed were filled up until in a comparatively short time a hard and level surface resulted, after which no repairs were necessary for many years.

Hardcore Foundations

McAdam's system proved absolutely effective and is used at the present day. More recently "hardcore" has been substituted for the broken granite, though the latter is retained as a surface material. Hardcore consists of big stones or a mixture of old bricks and concrete broken up into lumps about nine inches in diameter. The top layer of earth is dug away to the required depth and the hardcore laid out on top of the foundation. This is then rolled with a very heavy roller which crushes the hardcore into a solid mass, and on top of this is laid the broken granite, the whole being strewn with a loamy sand and water to fill up the cracks, and then rolled until it is a firm, hard surface. When it has dried out, and not before, traffic is allowed to pass over it.

The original type of macadamized road, while it was completely satisfactory for horse-drawn vehicles, could not be expected to withstand the faster and heavier motor vehicle. McAdam's roads were improved by the horse-drawn vehicle, since every load assisted in binding and consolidating the top surface; but motor-cars depend on the grip of the driving wheels to propel them, and instead of binding the surface material they tend to pull it apart. The rubber tyre passing over a water-bound road dislodges single stones here and there, thus allowing rain and other moisture to penetrate below the surface, undermining the whole road foundation. Motor traffic therefore requires a smoother surface, and heavier foundations which can resist heavy loads as well as the sudden compression and relaxation attending the passage of swift-moving traffic.

Modern Arterial Roads

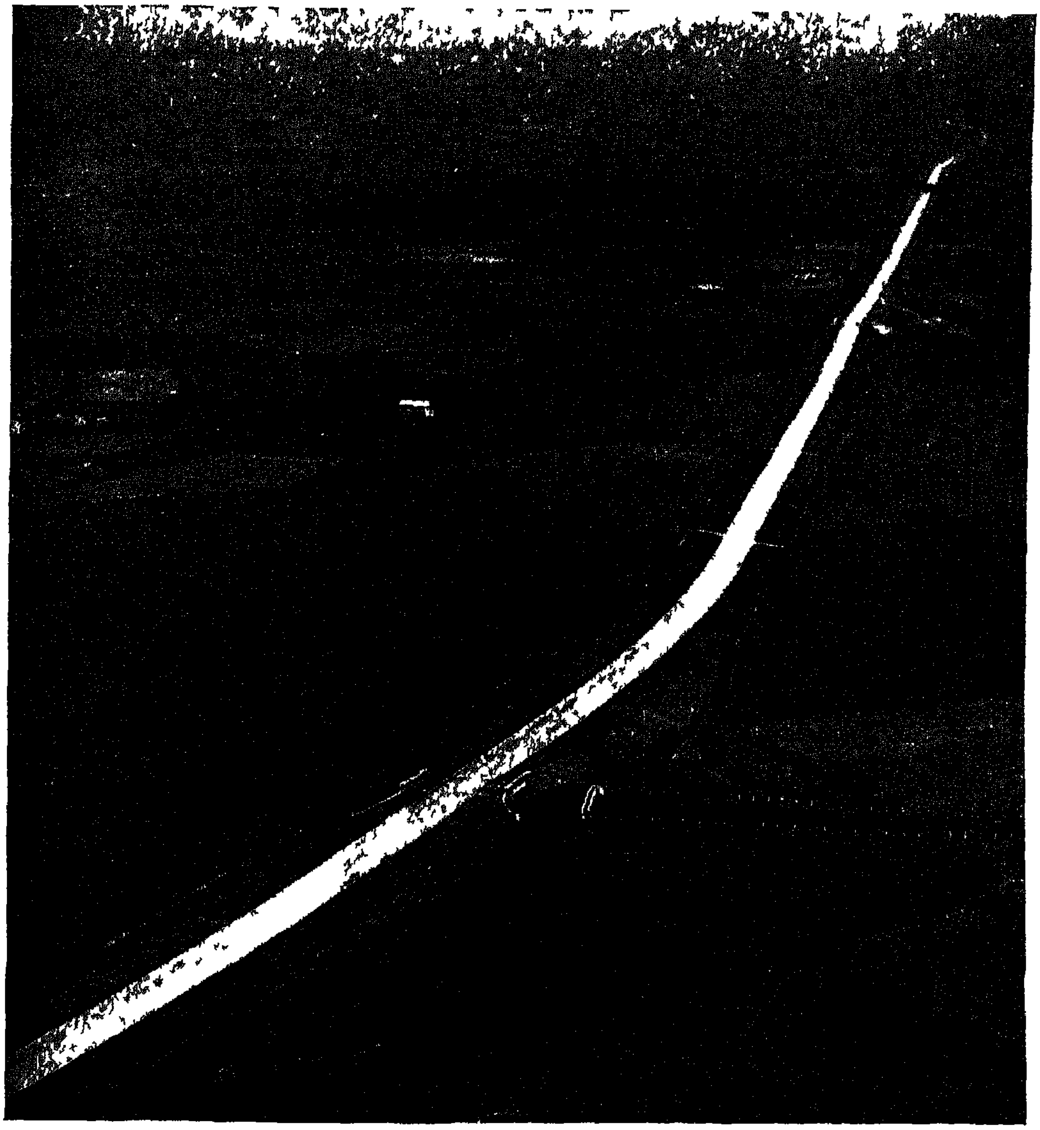
To-day our main arterial roads stretch through the very heart of the country and great care and expense is involved in planning and constructing them. For the most part, such roads consist of one carriageway, but in America two carriageways of narrower width running parallel with each other are favoured. While the broad, single carriageway allows for a greater volume of traffic, the duplicate system makes for greater safety, since the risk of head-on collisions is entirely averted. In Britain the arterial road system has naturally been built up from existing roads, which have been strengthened and repaired section by section.

The arterial roads for the most part are macadamized; but nowadays, instead of applying sand and water to the top surface to bind it together, it is usual to treat it with hot surface dressings, such as tar and bituminous emulsions. These dressings are applied on a perfectly clean road surface in warm weather, after which grit or granite shingle is thrown down and rolled in.

One of the advantages of a macadamized road which has been covered and sealed with tar or bitumen is that it is to a large extent free from the nuisance caused by dust flying up as a motor-car passes along it. The old type of road, because of the amount of dust thrown up from it, was a constant source of danger to the motorists themselves and the dust ruined crops growing along either side. While the road with a bituminous covering is undoubtedly superior for fast-moving traffic, its great disadvantage is the slippery nature of its surface. The search for a durable material that will allow motor-cars to travel swiftly but at the same time will be free from a slippery surface occasions much experiment by road engineers to-day.

Concrete, either plain or reinforced, has also come into vogue, but the former is preferred. Reinforced concrete is specially favoured for roads subject to fast-moving traffic and is used on many of the new arterial and by-pass roads throughout Britain. It is much employed, too, in America and on the European continent.

One of the problems that the road engineers of to-day have to solve has come about through the congestion of the roads in built-up areas. *Arterial* roads pass from one town to another, and the highways traverse busy cities. In crossing London, for example, during the busy hours of the day it may take a motorist an hour or even more to make his way through. Such travellers in transit add to the congestion in the city streets and slow down the traffic still more. In order to overcome this difficulty the main roads, as they approach big towns, are provided with by-pass sections which pass around the congested areas instead of through them. Thus, a motorist on a through journey is enabled by means of the by-pass to circumvent the busy towns on his route and proceed on his way more quickly.



Reminiscent of the arrow-like directness of the Roman road-builders—a fine stretch of modern arterial roadway at Kenyon Junction, near Leigh, Lancashire, viewed from the air

By-pass roads are seldom less than thirty feet in width and are more often than not constructed of concrete with footways on either side. Another feature of the same system is the road that completely encircles a city some half-dozen miles or so from its hub and enables traffic to pass around from

one quarter to another outside the congested area.

In Germany, recently. construction was begun on a highway 112 miles long around Greater Berlin. The object is to enable long-distance traffic between the cities of Germany within a radius of 150 miles of the capital to by-pass the congested area. The main highway is to pass from Henningsdorf in the north, eastwards to Buch, turning south by Alt-Landsberg and Kalkberge to Friedersdorf, where it turns west through Dahlewitz and Saarmund, bearing north at Ferch and Phoeben. It was originally planned to make radial traffic arteries to the centre of the city, but these were eventually abandoned. Branch arteries to such towns as Frankfort, Breslau, Stettin, Dresden and Leipzig will now join up to the main arterial circuit. The new highway will make it necessary to construct eighteen railway crossings and over 200 bridges and viaducts, two of which will be respectively 3,300 and 5,000 feet long.

The widening, straightening and general improvement of existing roads to cope with the greatly increased volume of road traffic has brought with it the companion task of clarifying signposts. This direction indicator on the Gloucester by-pass cannot leave much doubt in any road-user's mind

The Military Road

Roman roads, as we have seen, had definitely a military function, for on them the legions could swiftly travel to a danger spot and there quell a rising or repel an invasion. Whenever military operations are in contemplation the question of roads becomes of supreme importance. Over the marsh a road may be constructed of bundles of faggots; over less swampy ground a "corduroy" track of tree trunks laid transversely may be made; over the loose and shifting desert sand wire netting may serve to bind and anchor the road. When a punitive expedition goes into undeveloped terrain it will have to take with it an army of road builders scarcely less important than the fighting men themselves.

In Germany, there are many fine roads running from Berlin to the surrounding frontiers, and Italy also has some magnificent roads. Many of these thoroughfares, although used extensively for ordinary traffic, are essentially of military importance and have been built primarily with the latter end in view. The mechanized armies of to-day must have good roads which can withstand the passage over them of enormously heavy guns, of armoured cars and tanks, of lorries and tenders bearing loads of war material. Hence, on the Continent, the military road is assuming great significance. Log-roads, like those that were constructed during the Great War, will be virtually useless in future conflicts.

The German roads made especially for fast motor traffic are called autobahnen and, as a rule, consist of two carriageways 28 feet wide each, separated by a dividing strip of 16½ feet. The most important of these fast motor roads are the Cologne–Bonn, Munich–Salzburg, Hamburg–Lubeck and Frankfort–Darmstadt roads. The last-named is about 15 miles long, 8½ miles of which are surfaced with concrete, 5 miles with bituminous substance, and the remainder with stone setts. It traverses forest and agricultural land and has twenty-six bridges and road crossings. Altogether, nearly 1,000 miles of such motor roads are under construction in Germany.

For many years Italy's road system was the most unsatisfactory in Europe, but under the Fascist government it has been made one of the finest in the world. Among the many roads that have been built or are in course of construction are eight highways expressly for fast motor traffic. These roads are called autostrade; they are not part of the ordinary road system, but are toll roads which, although authorized by the government who partly bear the cost, are built by private corporations.

There are no speed limits on the autostrade, and drivers of all nationalities may be seen on them trying out their cars to fullest capacity. All autostrade have either asphalt or concrete surfaces, and the first to be completed, in 1925, was that from Milan to Lake Maggiore, with branches to Lakes Como and Varese.

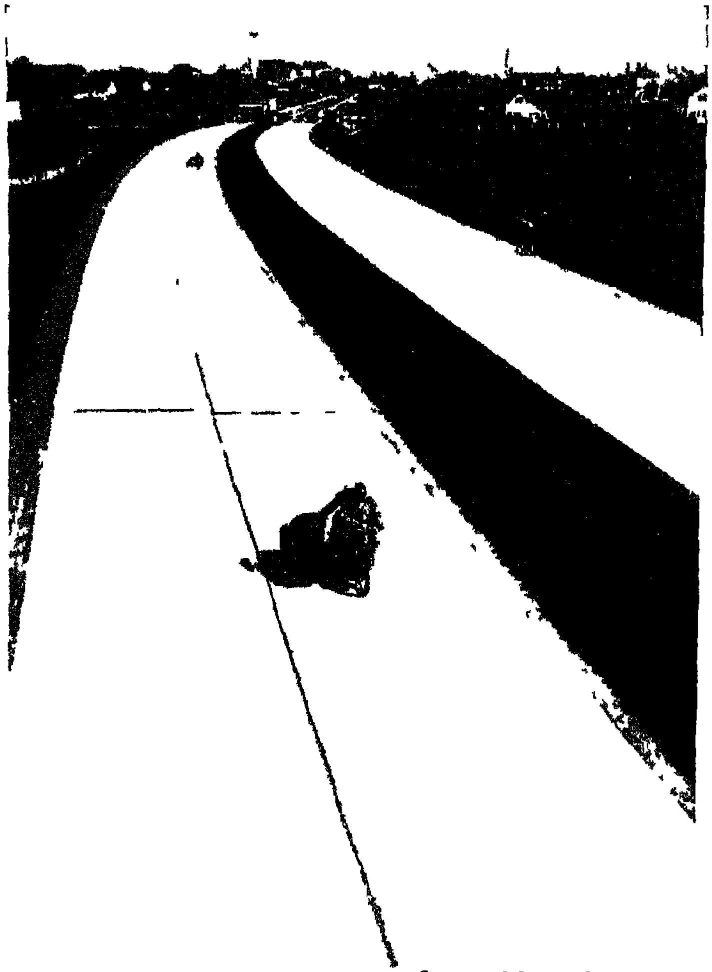
The first 20 miles of this autostrade is 33 feet wide with two side tracks of 6½ feet each. For the remaining 33 miles the road is 26 feet wide with two side-tracks of five feet each.

Photo Anderson

A boldly conceived effort of the modern Roman road-builders. The recently opened Via dell' Impero, Rome—a broad avenue driven through from the Victor Emmanuel Monument to the Colosseum

The curves on the road have a radius of 1,640 feet and the gradients are very easy. All the autostrade are constructed with a very slight gradient, and in that respect the modern Italian is following in the path of his Roman exemplar.

The Rome–Ostia autostrada is 14½ miles long and has the standard width of thirty-three feet; this road is toll-free, having been entirely constructed by the government. It is lighted by 2,000 lamps. The Milan–Turin is another autostrada and will eventually be extended to Venice, thus crossing Italy from west to east. This first stage in its development is seventy-eight miles long; it



Courtesy of German State Railways

has twenty-two large bridges, one of 1,000 feet over the River Sesia and one of 1,138 feet over the Ticino

One of the biggest feats that has been accomplished in Italy's road-building is a special transport highway to connect up the important port of Genoa with the Milan-Turin road. The first section of the road, from Genoa to Serravalle, a distance of twenty-nine miles, had to cross the Apennine Pass to Giovi. In order to avoid steep gradients, great tunnels were blasted out of the solid rock. In all, there are eleven of these tunnels with a total length of 1¼ miles. One of them is 2,996 feet long and another 2,952 feet. In addition to these there are twenty-eight bridges.

In Germany, a great network of national roads—called the *Reichsautobahnen*—is gradually being woven. The broad double carriageway seen here is on a section between Munich and Holtzkirchen

The Rome-Ostia autostrada is part of an extensive system of roads, reserved exclusively for motor traffic, which is being constructed in Italy. Special attention has been paid to lighting and the highway is illuminated by powerful lamps at twenty-yard intervals on each side. The Italian road-builders are thus worthily carrying on a great tradition

CHAPTER XVII
THE LARGEST PLANTS OF ALL

AMONG the deep, forest-clad mountain valleys of eastern California, under the shadow of the mighty peaks and ridges of the Sierra Nevada, what are probably the largest of all living things have their home: they are the famous "big-trees," or giant sequoias (*Sequoia gigantea*), and they are found growing naturally only amid this grand and rugged mountain scenery—the finest in the United States—and nowhere else on earth.

Californian Giants

The sequoias are cone-bearing, evergreen trees, related to the fir, cypress and spruce, but even the loftiest Norway spruce would be pitifully dwarfed beside one of these Californian giants. From the massive base of its straight, gracefully tapering trunk to its topmost branches the "big-tree" has an average height of about 275 feet; but individual specimens—veritable giants among giants—have far outstripped the average, and probably an estimated extreme height of a little over 400 feet—forty feet or so higher than St. Paul's Cathedral—would not be exaggerated This is the dimension claimed for a celebrated sequoia known as the "Father of the Forest," which stood for centuries with about a hundred of its fellows in the Mammoth Grove of Calaveras County, California, though a large portion of its pillar-like trunk has long lain prostrate on the ground. At the base this venerable giant had the enormous circumference of 110 feet, while even 300 feet above the earth its girth was forty feet. The hollow cavity of the fallen trunk forms a huge tunnel lofty enough for a man to enter on horseback.

The "Mother of the Forest," a neighbour and fitting companion of this splendid tree, has been dead for many years—the result of an intolerable piece of vandalism, when a considerable amount of its bark was removed for exhibition in the Crystal Palace. This "big-tree" was 327 feet in height.

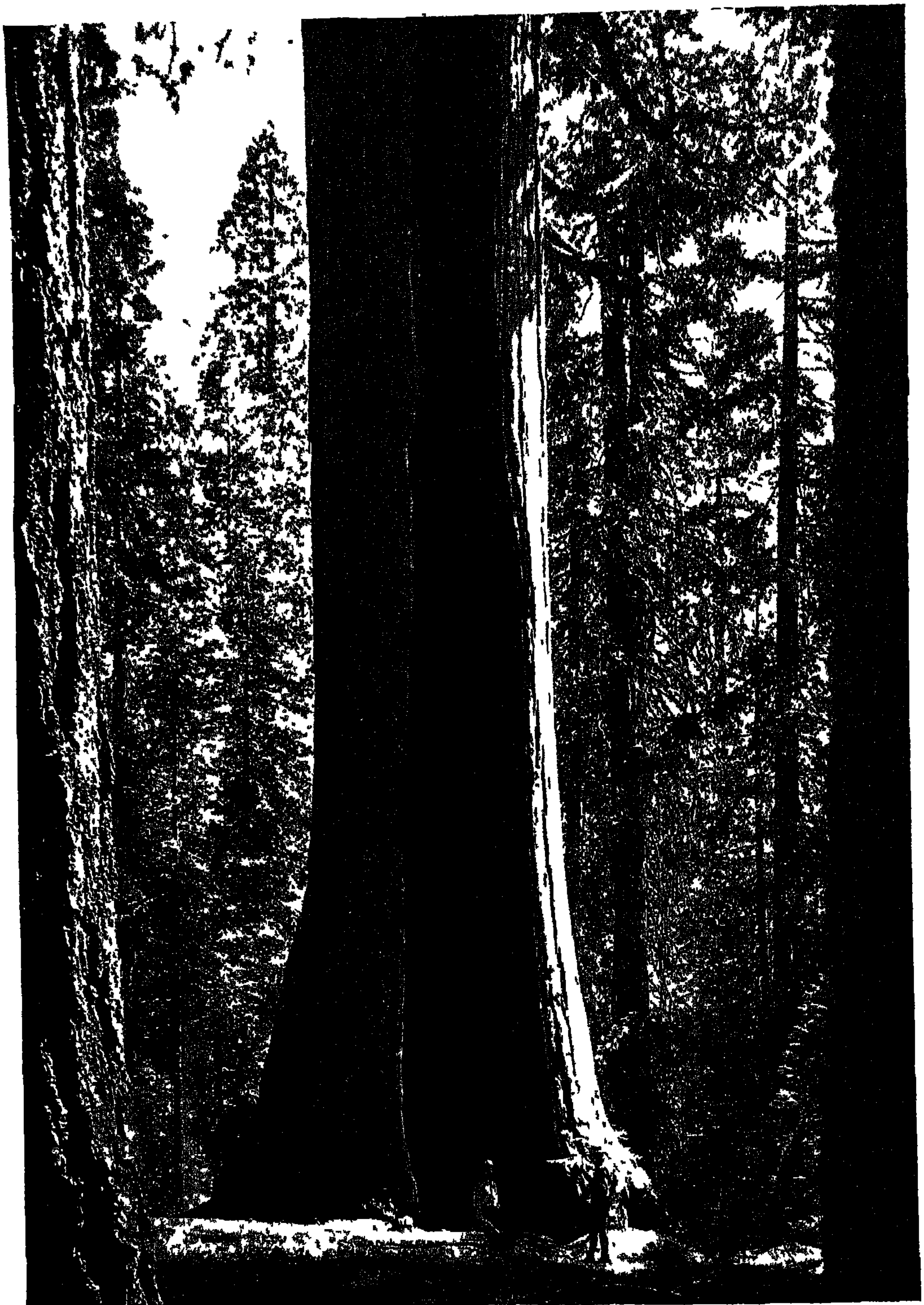
The Californian "big-tree" has the peculiarity of being found only in isolated groups, of which there are but ten altogether. The Mammoth Grove was discovered by a hunter in 1852—a period at which the greater part of the West was still wild and unexplored—and it is reputed to contain the largest and finest trees of all. But scarcely less imposing and far more numerous are the "big-trees" of the Mariposa Grove, farther south, several of which have a greatest circumference of more than 100 feet.

The great height of the sequoias is accentuated by the bareness of their column-like trunks, which may rise for 150 feet or so before any large branches are reached. The boughs are bent and drooping, and they are short in comparison with the height of the tree; while the tiny evergreen leaves are born densely on branchlets springing from the main boughs.

Towards the base the reddish bark of the "big-tree" frequently attains the immense thickness of eighteen inches; it is also very rugged and seamed and heavily marked with upright ridges and furrows. Above the great roots these ridges swell out to form enormous buttresses, broad and high enough to conceal several men, which firmly brace the lofty trunk against the pressure of the wind. The average diameter of these great trees, measured near the ground, is about twenty feet, but in exceptional specimens this may be almost doubled. In height alone, *Sequoia gigantea* is on the whole exceeded by the closely related redwood and by the eucalyptus, or gum-tree, of Australia, but as regards weight and bulk it is very unlikely that it has any rival in its claim to be the largest of living things; it is certainly the largest of all conifers, and this leaves in the field only the great gum-tree, regarding which we shall have more to say. A comparison with the animal kingdom is illuminating. The largest and heaviest of all known animals, existing or extinct, is the great blue whale, which in extreme cases may attain a length of over 100 feet, and a weight of more than 200 tons; while the weight of one of the largest and finest "big-trees" has been estimated at more than 5,500 tons.

The Oldest of All Living Things

The question of the age of these trees has given rise to much speculation. A section cut from a very large specimen is exhibited in the British Museum of Natural History, South Kensington, and its annual growth rings reveal an age of more than thirteen centuries. Outstanding dates in the world's history have been inscribed successively upon



Mondiale

Riven by fire from base to summit yet still bearing foliage like a normal tree—a huge *Sequoia gigantea* of California

With its trunk shaped like a bottle—the Australian Bottle-Tree (*Sterculia rupestris*) and (*right*) the 150 feet Kauri Pine (*Dammara australis*), found in New Zealand, which was regarded as sacred by the Maoris

the rings, so that the interested observer can trace the life of this great tree through the centuries. There is little doubt that the largest sequoias are among the oldest of all living things; one colossal specimen exhibited the growth rings of 2,425 years, though this would seem to be the oldest ever examined. During the early infancy of this aged giant the civilization of the Greeks was reaching its zenith, and the might and glory of the Roman Empire had not yet been dreamt of!

The great sequoia is very hardy and tenacious of life, and in the warm, sheltered valleys of the Sierra Nevada, where it grows to perfection, it has little to fear from climatic changes. Even forest fires, which annually destroy countless trees, can do it little harm, for it has the power of healing up great wounds in its bark by a protracted process of covering them over with new wood.

The only other existing species of sequoia is the so-called redwood (*Sequoia sempervirens*), which grows only along a narrow strip bordering the Pacific coast of North America, from southern Oregon as far southwards as San Francisco; it is not found in localities free from heavy fogs and rain, which seem to be essential to its welfare. The redwoods grow thickly massed together, the closely-serried rows of their lofty stems making a fine spectacle. Though taller on an average than the "big-trees," and sometimes reaching a height of more than 400 feet, they are not so thick as their big relations and do not contain so much timber. However, the timber of the redwood is, of the two, much more valuable in joinery, and in consequence the numbers of these magnificent trees, which at one time formed dense forests, have been sadly depleted.

The redwoods have great, red buttressed trunks, similar to those of the "big-trees";

Courtesy of the Australian National Travel Assn. and the New Zealand Govt

but they are, if anything, more graceful, especially in youth, when their long, pendant branches touch the ground. This sequoia owes its specific name of *sempervirens*—"ever living"—largely to its power of passing without serious harm through the most devastating forest fires, for the trunk of the living tree contains a considerable amount of water, with little inflammable matter, and will not burn in consequence. Moreover, the redwood has great vitality, and even when cut down to the root, it will spring up again and again from the same stump.

Courtesy of the Australian National Travel Assn.

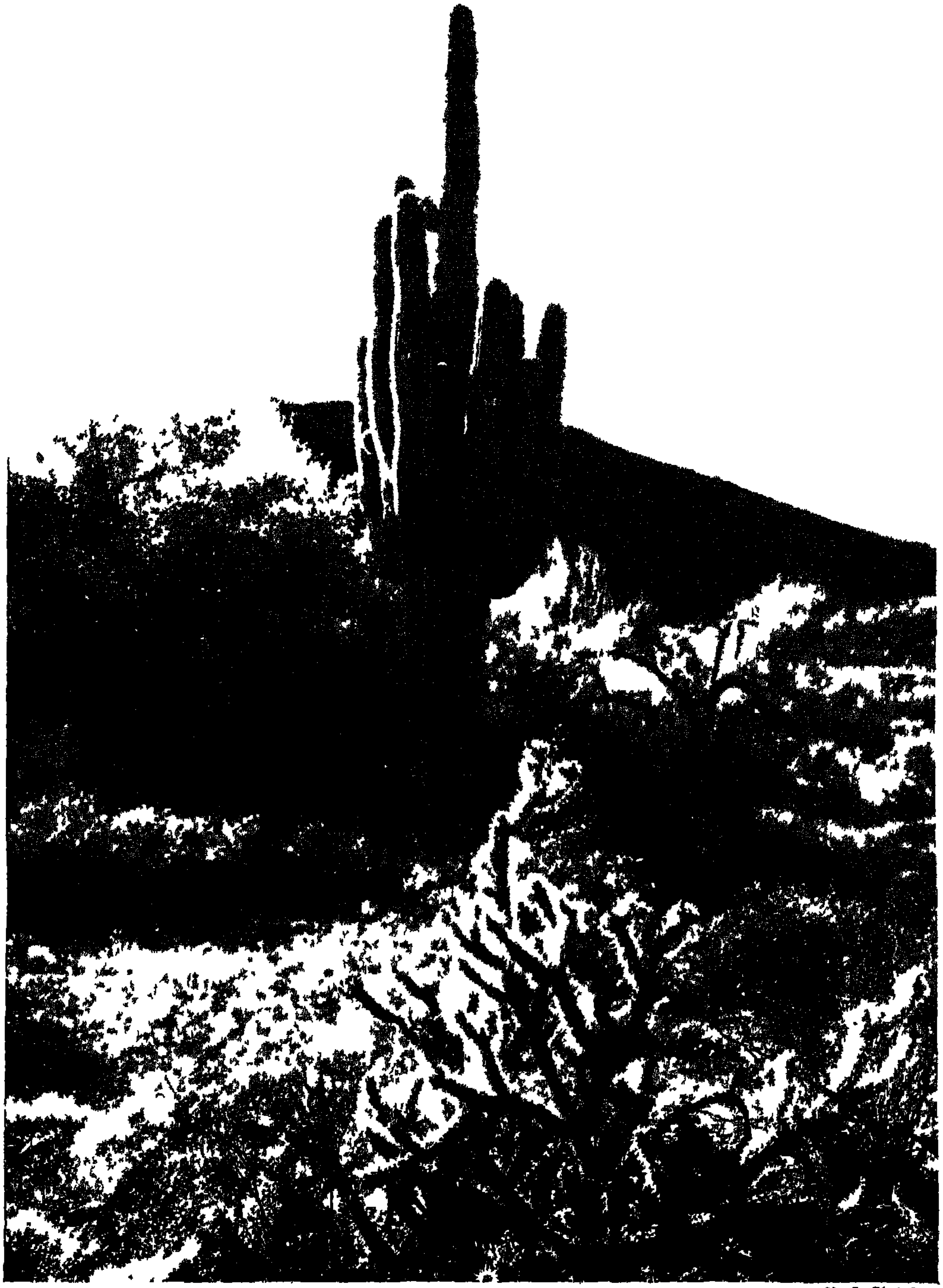
The straight trunk of the Australian Gum Tree often towers 100 feet or more without a branch. Gum trees lose their bark, which flakes off in long curling pieces, but retain their leaves

Though so restricted to-day in their natural habitat, there is abundant evidence that the giant sequoias were at one time fairly common throughout the more equable parts of the northern hemisphere, including the British Isles. But during the Glacial Period, when vast regions of the northern latitudes were covered with a sheet of ice, the sequoias almost entirely died out, surviving only in those regions of the United States bordering the Pacific where they are still found to-day.

Everywhere throughout the dense, dusty bush and sombre forest-land of Australia—and notably in the vast district of Gippsland, in south-eastern Victoria—flourishes the giant gum-tree, or eucalyptus, which is a relative of the myrtle and is distinguished, as we have already indicated, as being the tallest tree in the world. This splendid gum (*Eucalyptus amygdalina*) has a uniformly round bole and smooth stem—in strong contrast to the furrowed, buttressed sequoias—which rises for a height of sixty feet or so before any branches appear. The long, leathery leaves of the gum hang downwards and have their edges turned towards the sun, so that the shadow which they cast is scarcely perceptible; distilled with water, they yield a variety of the familiar eucalyptus oil.

The great gum is on the whole loftier, though relatively more slender, than the sequoias, and in some districts there are many specimens with an average height of more than 300 feet. But these dimensions may be exceeded considerably on occasion; in 1930, for example, according to official records, the largest tree measured had a height of 346 feet. The largest gum on record—and perhaps, also, the loftiest tree that has ever been known—was discovered lying on the ground in Victoria; it had the colossal length of 470 feet, with a maximum circumference of eighty-one feet.

Although eucalypti are quick-growing trees, the timber of most of the numerous species is very hard and dense, and is therefore employed extensively for carpentering and shipbuilding. One well-known species, the blue gum, has been planted in large numbers in Egypt, India, Natal, Algeria, the marshy Roman Campagna, and many other localities where malarial fever was formerly very prevalent; and in most cases the direct result has been to convert a pestilential region into a salubrious and habitable one. The improvement is not attributable to the antiseptic vapours given out by the oil-secreting leaves, as was formerly imagined, but to the drainage of an enormous amount of



H. J Shepstone

A Giant Cactus (*Cereus giganteus*) of the American Dry Lands, nearly 40 feet high. Note the holes in the upper limbs—the nesting-places of desert birds

water from the soil by the great roots The blue gum is also a giant, a height of 375 feet —ten feet higher than St. Paul's Cathedral— being on record for this species.

If the giant gum of Australia is the tallest of trees, the one that covers the greatest space is undoubtedly the banyan of India and the East Indies, which is a close relative of the common fig tree. The banyan most usually commences its life as an epiphyte, or parasite, upon another tree, frequently upon a palm. Seeds dropped by birds lodge in the crown of the palm and there germinate. After a while the young plant puts forth a number of slender aerial roots, which grow downward until they reach the ground, and then develop an ordinary root system below

Photo Richardson

Courtesy of the Southern Rhodesian Govt

Huge shrubs of South Africa. The Giant Euphorbia, or Candelabra Tree, from Rhodesia and (*left*) a beautiful species of Aloe, crowned by a scarlet plume, which grows in the desert lands of the South-West

the surface. Gradually the aerial parts of the root thicken into stout trunks crowned with spreading branches, which in turn throw out long pendulous rootlets towards the ground.

The luckless palm that serves as a host is eventually strangled, but the banyan goes on growing and spreading, throwing out long, prop-like, adventitious roots *ad infinitum* and in time covering an enormous area. The huge, labyrinthine tree soon becomes the home of innumerable monkeys, bats, birds and insects, and the uninformed traveller frequently mistakes it for a small wood or grove containing many separate trees. It is not uncommon for an entire native village to be located under the generous shade of a single banyan.

There is a well-known banyan in the Royal Botanic Gardens at Calcutta, not yet a century and a half old, whose parent trunk has a girth of more than forty feet; in addition, there are between two and three hundred upstanding, trunk-like roots, while the entire tree covers a space that is probably about 900 feet in circumference. But the largest banyan on record would seem to be a hoary old patriarch that stood on the banks of the Nerbudda River; described as a

Courtesy of the Southern Rhodesian Government

Known as "The Sentinel of the Savanna," the great Baobab Tree (*Adansoni digitata*) of Africa bears a gourd-like fruit called "Monkey Bread." The tree on the right is 77 feet in circumference

Photo· E. Baena, Teneriffe

The Dragon-tree (*Dracaena draco*), a native of the Canary Islands, is remarkable for its longevity. Here is a magnificent specimen growing at La Laguna, Teneriffe

phenomenon by the captain of the fleet of Alexander the Great during the return from the latter's Indian expedition of 326 B.C., it was credited by another traveller twenty-one centuries later with a circumference of more than 2,000 feet, even though a great part of it had been destroyed from time to time by the rising of the river during floods. In its prime, this enormous banyan is said to have been capable of sheltering no fewer than 7,000 people at once beneath the far-spreading canopy of its innumerable branches.

There is another fig, the Indian rubber tree of the East Indies, which also has a remarkable root system. This tree grows to a great size, and many of its roots

protrude, partially exposed, above the surface of the ground; so that in an old specimen they resemble an army of enormous snakes or lizards, all writhing in fantastic and contorted attitudes around the base of the gigantic trunk.

One of the most remarkable of all the many strange plants found in Africa is the baobab tree, which can probably claim a double record in regard to age and the thickness of its trunk. In height this tree is not at all exceptional, but its squat, sturdy stem may grow to the enormous thickness of thirty feet, or even more; so that, the wood being very soft, it is quite common for it to be hollowed out by the natives and made into a house, capable of accommodating an entire family in comfort. The branches of the baobab droop low towards the ground, covering the tree with an enormous, round mass of foliage; and the biggest branches may themselves be several feet in thickness. The large leaves of this curious tree, pounded up, form a staple article of diet among the natives of tropical Africa, while the juice of its large fruit—known as monkey bread—yields a cooling drink containing much citrate of magnesia.

The bark of the baobab has medicinal properties, and its fibres are woven into ropes and native cloth, but the wood is far too soft to have any value as timber. The baobab flourishes throughout the hotter parts of Africa and Madagascar, and it has been introduced successfully into tropical districts in other parts of the world. It is believed by botanists to be among the longest-lived of all growing things, and very large specimens have been credited by some authorities with the enormous span of 5,000 years.

In the Canary Islands, and especially in the island of Teneriffe, grows the dragon-tree, which is related to the yucca of our botanical gardens, and is celebrated alike for its longevity and for the enormous girth attained by its trunk; incidentally, it yields the valuable resin known as "dragon's blood." The growth of the dragon-tree is very slow, but it seems to go on indefinitely. A large specimen examined by the famous scientist, von Humboldt in 1799 was found

Photo. A. W Exell

A grove of beautiful Tree Ferns (*Cyathea manniana*) growing at an altitude of 5,000 feet in the Moka region of Fernando Po in the Gulf of Guinea. The Tree Ferns of this part of the world are notable for forming small woods in which they are the dominant species

Courtesy of the New Zealand Government

A noble specimen of the handsome Tree Fern growing on the shores of a New Zealand lake. The drooping fronds often attain a length of 25 feet to 30 feet

to be about 75 feet in height and 50 feet in girth; in the centre of its immense trunk there was a spacious cavity ten feet across. When Teneriffe was conquered by the Spaniards, at the end of the 15th century, this splendid dragon-tree was scarcely any less in size, and from careful observations of the rate of growth of these trees its age has been placed at more than 5,000 years. It was still in a flourishing condition when its long life was abruptly terminated by a hurricane in the year 1868.

The humble yet graceful ferns that grow in such profusion in the shadiest corners of our gardens and in the moist, secluded woodland dells do not usually form very large plants; yet many of their relatives in the tropical and sub-tropical parts of the world attain such a prodigious height and girth that they may practically be regarded as trees The trunks of these giants are not composed of true wood, but of the densely compacted bases of the fronds; and in some species they are boldly marked with a spiral

pattern of scars left by dead fronds as they fall away. In large specimens the tough, tapering boles may rise, straight and bare of branches, to a height of fifty feet or more—the stature of a forest tree—bearing a great crown of gracefully pendent green fronds.

In many uncleared regions of the tropics—in Africa, Brazil, Australia and the Pacific Islands—the tree-ferns stand in dense groves and forests among the mountain ravines, forming such a beautiful, though strange and even fantastic, landscape as might have been familiar to the great lizards that lurked in the stifling heat of the primeval coal forests. But it is in the fertile soil of Norfolk Island, in the southern Pacific, that the tree ferns reach their greatest dimensions, and here old specimens may tower to a height of sixty or even eighty feet, proudly vaunting their enormous canopies of elegant fronds over a great area. Unfortunately, owing to the fact that the soft pith found in the trunk of the tree-fern is greatly relished by pigs, the numbers of this curious and beautiful plant have been greatly diminished.

Photo: the late H. G. Ponting

Enormous grasses flourishing in a dense clump 100 feet high—Giant Bamboos at Peradeniya, Ceylon. The bamboo has many commercial uses and is very common in tropical Asia

From the tallest of trees and ferns to the tallest of grasses is not so wide a remove as might be expected, for the bamboo, the largest of all grasses, not infrequently attains the height—though not the girth—of a forest tree. It is one of the most quick-growing of all plants, and in some species may grow three feet or more in a single day; while after the first three months of growth, the green feathery crown of this remarkable grass may wave 120 feet or so above the ground. A bamboo stem has even been known to reach a height of 170 feet, which seems to be a record. So remarkably strong and fibrous are these giant grasses, under their shiny, flint-like varnish, that stems of the most extreme length have a maximum diameter of but little more than a foot, which in the case of the majority of real trees would be woefully inadequate to support a trunk of similar height.

Throughout all the hotter parts of the world, but especially in tropical Asia, the dense, lofty clumps of slender bamboos are

one of the most familiar sights, and this ubiquitous grass has powerfully influenced the arts and industries of all the many peoples who have relied upon it for centuries to fulfil the multitudinous needs of their daily life; indeed, it may be said with truth that the East would not be the East without the bamboo. In many parts it is almost the sole building material known; and bamboo houses, when skilfully made, are strong, durable and cool, as well as pleasing to the eye. The split stems are woven into light and comfortable furniture, into mats and partitions, and into basket-work of extreme fineness.

Excellent buckets, bottles and cooking utensils are furnished by simple cross sections of the larger stems, the stout partition that closes each joint forming the bottom; while whole stems with the partition bored throughout are in many lands the only available water conduits for tanks and fountains. Bridges, ladders, poles, ropes, cables and the masts of ships—as well as spears, bows and arrows among the instruments of war, and pens and paper among those of peace—are all furnished by the indispensable bamboo; its ample bounty even extends to the delights of the table, for the young shoots, when boiled, are not inferior to asparagus, and pickled in company with the succulent rhizomes they make a very tasty condiment.

In many eastern countries—China is a notable example—the economic life of the people is so dependent upon the bamboo that the plant is regularly cultivated on a large scale, and the extensive plantations of these monster grasses, covering many acres with their slender, waving stems and fresh green leaves, make one of the most delightful of ordinary spectacles.

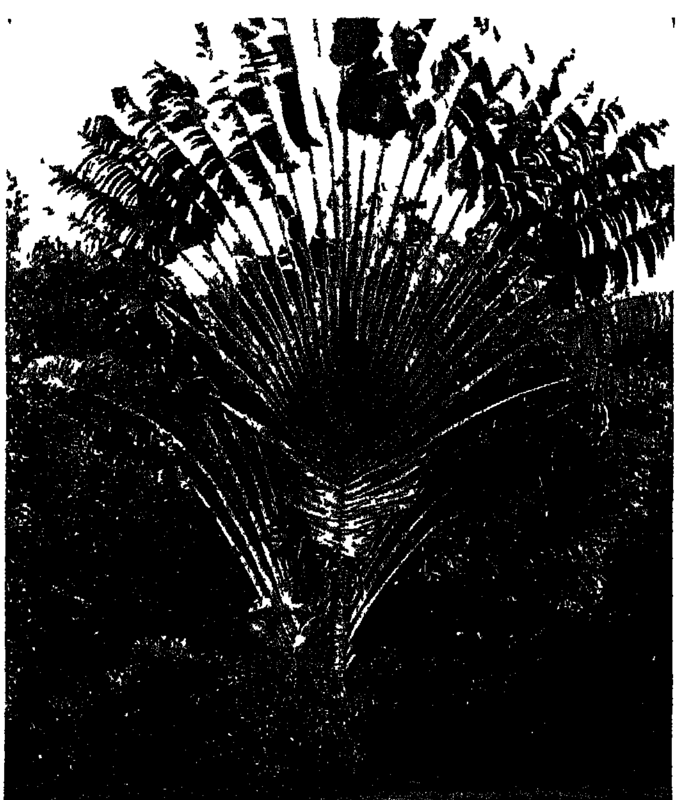
Courtesy of the Australian National Travel Assn.

Tufted Grass Trees, or "Black Boys," of Western Australia. These curious plants produce a mass of long rush-like leaves which are eaten by cattle

Almost rivalling the bamboos in economic importance, but far outstripping them in length, are the so-called "rattan canes," which actually are palms, though in the state in which they are usually encountered in commerce they bear very little resemblance to the popular conception of a palm. The rattans, of which many species exist, are among the commonest plants in the dense, steaming jungles of the East Indies and the tropical regions of Africa, India and China, their great profusion and intense toughness making them one of the most formidable

obstacles to a passage through the forest; for the leaves of the rattans are furnished with numerous long, hooked spines, by means of which they are able to cling to other plants and drag themselves upwards through the dark foliage towards the sun. These spines are never seen in imported canes, since they are stripped off by the natives before the rattans are dried and marketed.

So stern is the struggle for existence in the crowded condition of a tropical forest, where hundreds of plants of different kinds are thirsting for the life-giving sun, that the slender, climbing rattans may have to insinuate their way upwards for hundreds of feet before they reach the roof of the forest and attain their goal; and for this reason these indomitable palms have probably the longest stems in the whole of the plant world, often reaching the enormous length of 500 or 600 feet—through the whole of which distance, it may be remarked, the sap has to be ceaselessly driven upwards by the root, in order to supply sustenance to the plant and compensate for the heavy loss of moisture in the tropical heat.



A peculiar fan-shaped plant from Madagascar which accumulates quantities of water at the base of its leaves—the Traveller's Tree (*Ravenala madagascariensis*)

Among the multitude of useful things fashioned in the East from the tough, fibrous and flexible stems of the rattans are ropes, mats and many forms of basket-work, while in the West they form the familiar implements for clearing obstructed flues and pipes, and are also used, after being cut into strips, for caning chairs.

Flowers of extraordinary dimensions are not uncommon in tropical lands, where in practically every detail of creation Nature has set about her work with a prodigality unknown in cooler climes. So it is not surprising that the largest of all known flowers should be found, though even then but rarely, in the dark, hot-house atmosphere of the luxuriant jungles of Sumatra, where tigers and elephants roam through the dense undergrowth and where bats, apes and gigantic spiders populate the gloomy realms below the tree-tops—a fitting home indeed for this most fantastic, most repulsive and most unreal of all blossoms. The *Rafflesia arnoldi*—it has no European name other than that given to it by botanists—is a parasite growing upon the exposed roots of a kind of vine and drawing its sustenance from the life-blood of its host. It has neither stalk nor leaves of its own, and its roots are buried entirely within the tissues of the plant on which it grows; so that all that is visible of *Rafflesia* is its prodigious, cabbage-like bud and, later, its enormous blossom. When the latter is fully open, its thick, fleshy, backwardly-curled petals—five in number—lie flat upon the ground, covering a space at least three feet across; while in their midst lies the shallow, bowl-shaped vessel containing the anthers, which is capable, it is said, of holding about two gallons of water. The weight of the whole blossom falls not far short of fifteen pounds.

The fertilization of *Rafflesia* is carried out in a wonderfully ingenious yet most repulsive fashion, for the monstrous blossom is coloured red like blood, while at the same time it exhales the nauseating stench of carrion, so that it can easily be mistaken for a mass of decomposing flesh. Attracted by

this lure, large numbers of flies visit the parasite and are even induced to lay their eggs within it; and through their intervention the pollen is carried unfailingly from one blossom to another. The sowing of the ripened seeds has been provided for in a manner no less ingenious, though perhaps less certain. It must be borne in mind that these seeds will germinate only in the tissues of one particular vine, and if they were merely scattered upon the ground they would perish without taking root. However, they are very sticky and cling tenaciously to the feet of elephants, rhinoceroses and other animals when these beasts are forcing their way through the jungle. Subsequently, these clumsy and unwitting gardeners may bruise the roots of the vine that is to serve as host, and at the same time leave a seed of *Rafflesia* in the damaged tissues. Here it establishes itself, striking its roots deep into the flesh of the vine, which swells into a dome-shaped protuberance, through which there at last breaks a monstrous bud.

Ewing Galloway, N.Y.

With a central yellow rim and five huge brick-red petals with whitish raised spots, *Rafflesia arnoldi,* the largest flower in the world, measures three feet across and is found in Sumatra

This remarkable plant was not seen by a white man until 1818, when it was discovered in the dense Sumatran jungle by one Dr. Arnold and made known to the scientific world by Sir Stamford Raffles, the great colonial administrator, after whom it received its name. It is one of the rarest of plants, perhaps because the manner of its distribution is dependent so largely upon chance.

After the largest flowers, let us look at the largest leaves in the world, though here it is no easy task to come to a decision. Perhaps the largest of all simple leaves is that of the banana, which may be ten feet or more in length;. but in compound leaves—those made up of a number of separate leaflets—this length may be greatly exceeded, as in the case of many palms, particularly a magnificent species that is found in Brazil, in the damp, sultry heat of the Amazon valley. The highly compound, feather-like leaves of this splendid tree commonly measure forty feet in length, and have a width of six feet or more. From the same region hails one of the most celebrated of all plants, the pride of botanical gardens and of wealthy amateurs of horticulture throughout the world—the gigantic water-lily, *Victoria Regia,* whose round, floating leaves may boast the enormous diameter of seven feet.

This water-lily is found growing in great profusion in the backwaters and swampy pools fed by the Amazon and its tributaries, but it is seldom, or never, found in th
stream—for it is a lover of c *M. Synge*
Here it spreads out its gr *gonensis.* **This**
ke,'' flourishes in a
the full glare of the sun **ganda border**
surface of the water

Courtesy of the Booth Line

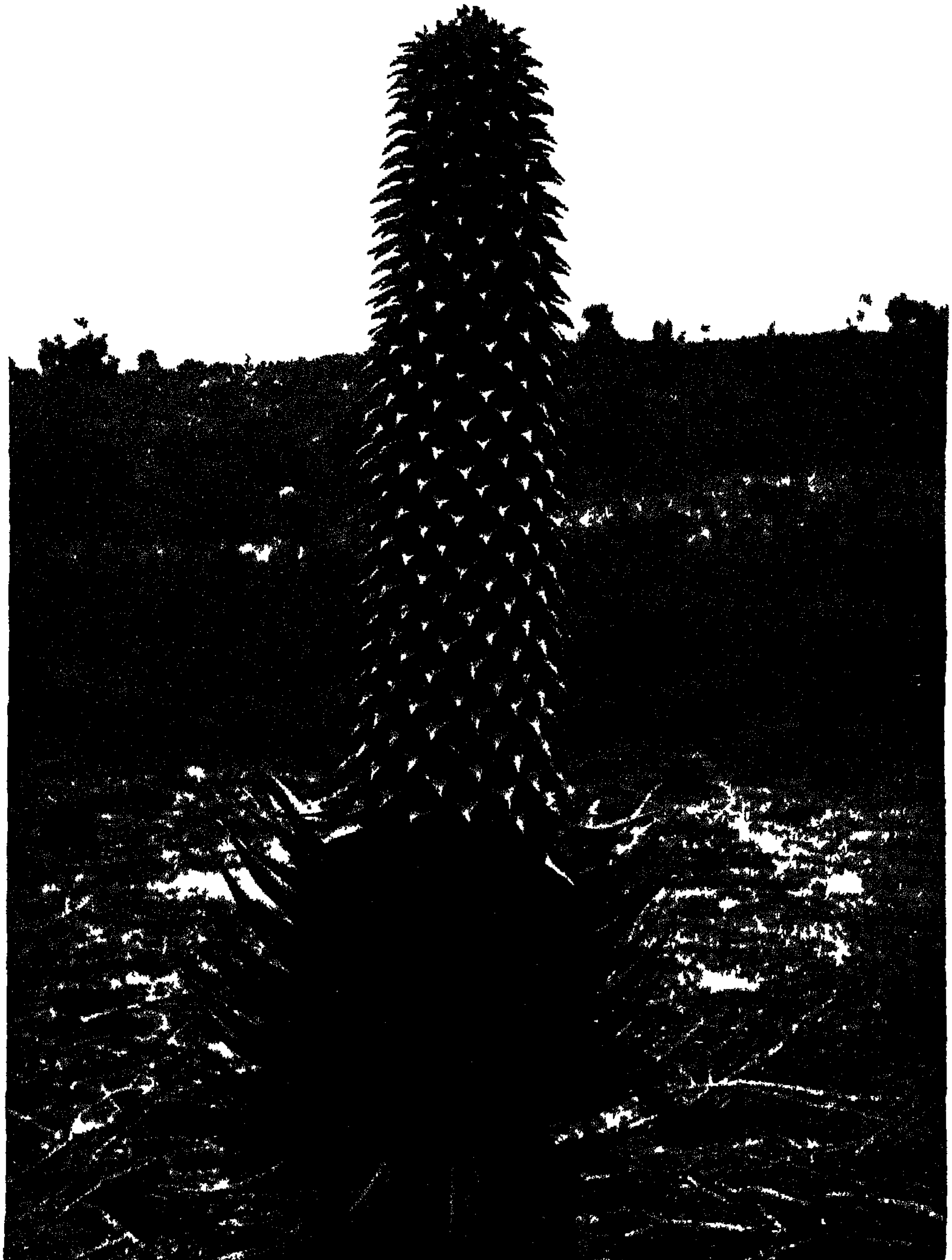
Like floating saucers on an Amazon backwater—*Victoria Regia*

The great water-lily the leaves of which are sometimes twelve feet across

Courtesy of the British Museum Expedition to East Africa

Hardly recognizable as being akin to the common Groundsel

A peculiar fan-shaped pl... of the enormous *Senecio elgonensis*, high up on an African mountain-side
tities of water at the base



British Museum Expedition to East Africa *Photo Patrick M. Synge*

Cousin to the familiar Lobelia of the garden bed and truly a botanical curiosity—*Lobelia elgonensis* This amazing plant, "a great rosette of dark green leaves from which emerges an obelisk-like spike," flourishes in a weird wonderland of giant vegetation, 10,000 feet up on Mount Elgon, on the Kenya-Uganda border

dainty little jacanas—water birds with extremely long, slender toes—pick their way fastidiously all over these leafy rafts and step from one to another as though they were stalking over the dry land. The edges of these curious leaves are turned up perpendicularly for two inches or so, like the rim of a large flat tray, which gives the leaves such a strong resemblance to the wide clay ovens in which the Indians bake their bread of mandiocca flour, that they are universally known throughout the Amazon valley as "the jacana's oven." Underneath, the leaves are purple and are marked with huge corded veins beset with prickles.

The flower of "the jacana's oven" is very large and beautiful, being more than a foot across, tinted white and rose, with a delicious scent. The enormous fruit yields floury seeds which are greatly relished by the Indians, so that an alternative name for the huge plant is "water maize." According to Alfred Russel Wallace, who visited *Victoria Regia* in its native haunts, the stems are capable of growing to a great length, for during the rainy season the flood water of the Amazon may rise as much as twenty or thirty feet, with the leaves and blossoms of this giant water-lily floating serenely on its surface.

Many amateur gardeners would be not a little surprised to learn that the charming little blue lobelia of their flower borders has giant relatives of weird appearance growing at an altitude of 10,000 feet on the mountains of East Africa. Here too are seen in profusion certain gigantic cousins of the common groundsel and the lady's-mantle. It had been known that in this lofty region there were many botanical curiosities, including plants in which mountain life had produced, strangely enough, a giantism—usually such conditions tend to bring about a dwarfing. In 1934 a British Museum Expedition went to East Africa to study plant and insect life, and by courtesy of the authorities we are able to reproduce photographs of some of these "wonders."

Courtesy of the British Museum Expedition to East Africa

In the mysterious highland forests of Mount Elgon, 12,000 feet above sea-level, there grows the great *Hagenia* tree—a giant relative of the little Lady's Mantle of English fields

CHAPTER XVIII

WONDERS OF THE RAILWAY

FOR something like a century, trains have been whirling day and night, carrying countless millions of human beings to their destinations and bringing billions of tons of goods to the world's markets. Day and night for a hundred years, pioneers have been surveying desert and jungle and swamp, the beasts of the wild prowling about their camp-fires in the darkness. Armies of men have been tunnelling roads through the adamant heart of the mountains. Still others have laboured in caissons at the bed of the sea or with mighty rivers rushing by them, planting the piers of great bridges. Viaducts have been built, spanning great valleys. A century—and now the whole land surface of the world is threaded with those parallel ribbons of steel which, linking country to country, have helped to bring the nations of the world closer together.

Courtesy of the G.W.R.

In the Erecting Shops at Swindon, showing engines in various stages of repair and a 100-ton overhead electric travelling crane lifting a 2-8-0 tank engine

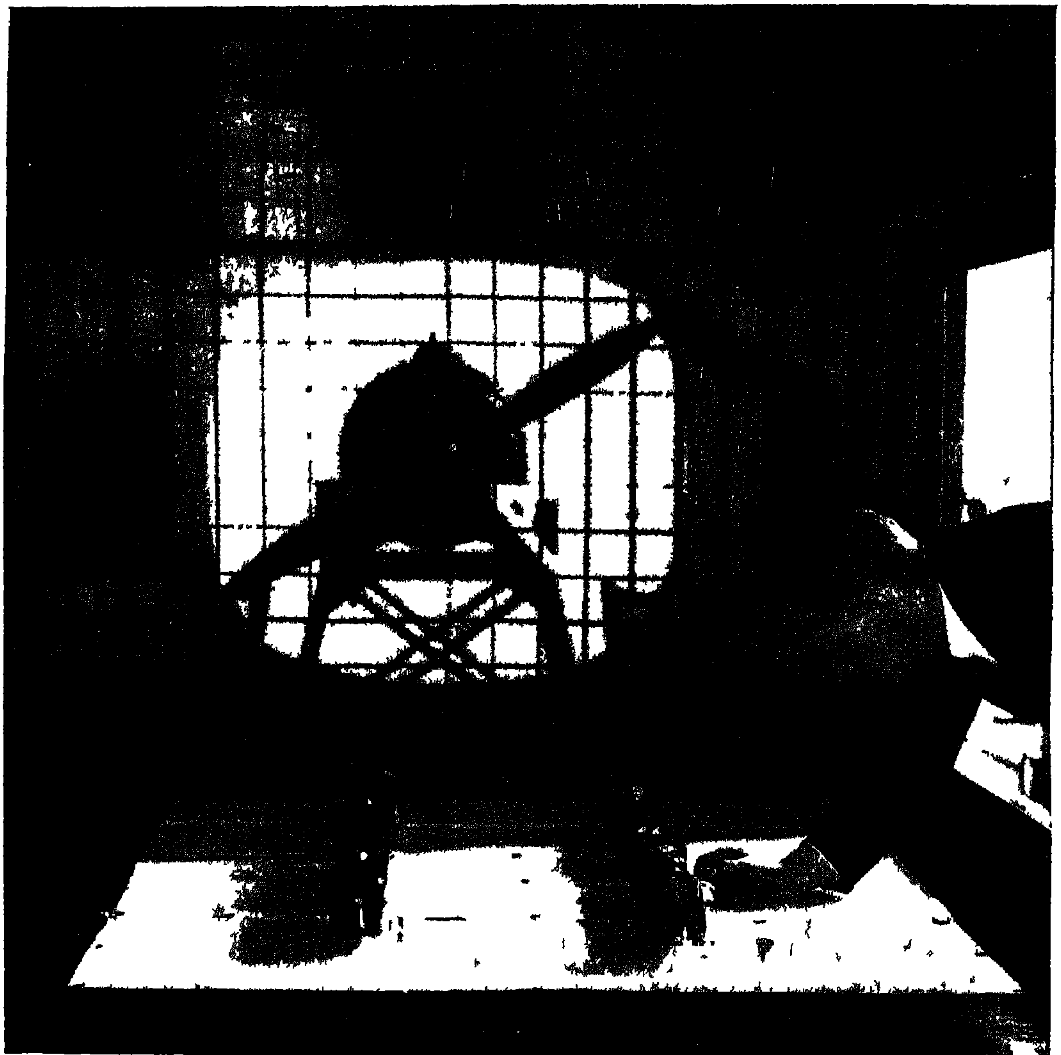
In the modern steam-locomotive works, with its many "shops," is an enormous variety of machinery, from the rolling mills and huge hydraulic presses used to construct great boilers, to the high-speed automatic machines which turn out small parts. At the L.M.S. works in Derby a five-ton steam-hammer is used to forge various locomotive parts out of red-hot billets of steel. The immense machine is controlled by one man working one light lever, and the operator becomes so skilful that in his forging he can graduate the hammer from maximum power to a blow barely sufficient to crack an egg.

Locomotive cylinders are cast from specially selected close-grained iron or steel, and after casting are planed and bored and turned. In the steam-chests special machines bore in one operation the holes to receive the piston-valve bushes. In order to dead-fit

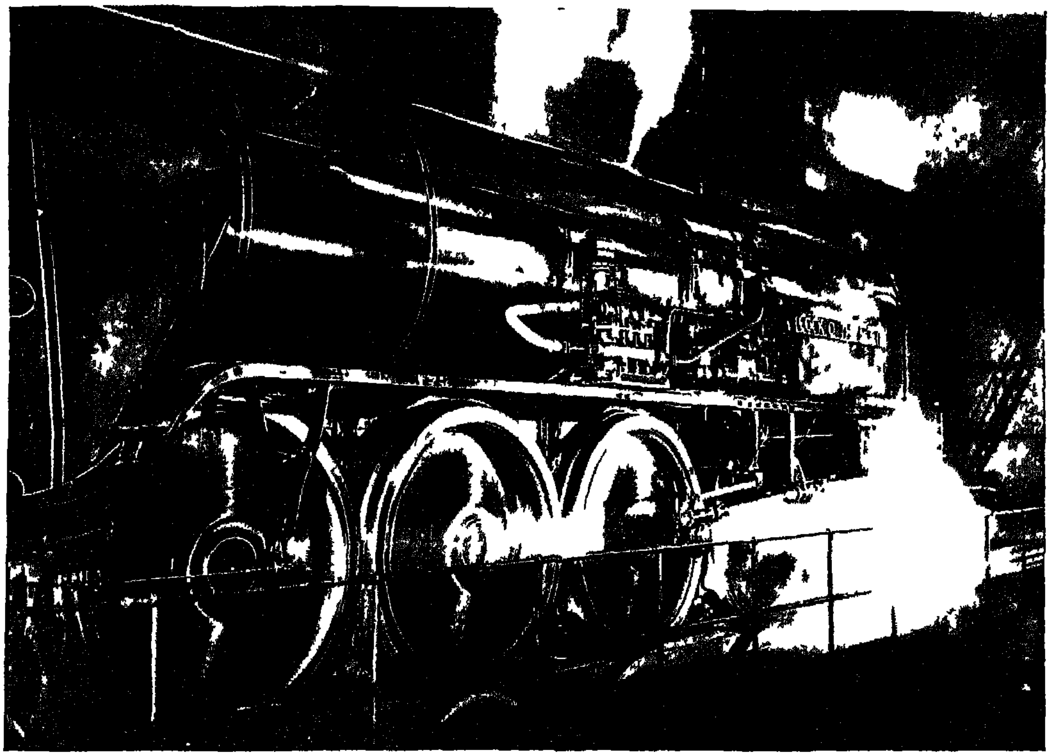
them into the holes, the bushes are "shrunk" by being dipped in a tank of chemical freezing mixture. Once inserted, the bushes regain their normal size and make a tight fit in the casting. The frames forming the sides of the under-carriage are cut to the required shape from steel plates by the use of an oxy-coal-gas flame. They are then slotted, drilled and tapped to receive the cylinders and "motion," and the many other components which are bolted on the locomotive-chassis.

Steel webs are machined and bored for the bars on which they are shrunk to form the built-up crank axles; or the entire axle may be forged from the solid. Round the webs, after these have been machined, hoops of steel are shrunk to give additional strength. The axles are required to stand a tensile strength of forty tons per square inch. The locomotive wheels, made of cast steel, are next bored to receive the axle ends. These latter are forced in under hydraulic pressure. The tyres, made of special steel, are then shrunk on to the wheels.

Boilers are designed to conform to the available space on the engine chassis, and consist of a fire-box, a barrel, and a smoke-box. The steel plates which form the fire-box are flanged by hydraulic presses which bend the metal over the shaped dies. After it has been furnished with its flue tubes and those for the superheater, and has been fitted with water-gauges, injectors, safety-



Research work to aid the railway engineer. Comparing the wind resistance of streamlined and standard trains by means of models in the wind-tunnel at the L.M.S. Research Laboratory at Derby



With her wheels revolving at top speed while the engine stands still—the L.N.E.R. locomotive "Cock o' the North" being tested for hauling power at the Vitry experimental station, near Paris

valves and the other accessories, the completed boiler is tested—first under hydraulic pressure and then at working pressure under steam. A highly important part of the work is the lagging of the entire barrel of the boiler with a "blanket" of asbestos or some other non-conducting material to prevent heat loss. Outside this come the clothing plates that we can see. The boiler is rigidly bolted to the frames only at the smoke-box end, since the barrel must be free to expand under heat; at the fire-box end it is attached by means of expansion brackets that allow a certain amount of longitudinal movement.

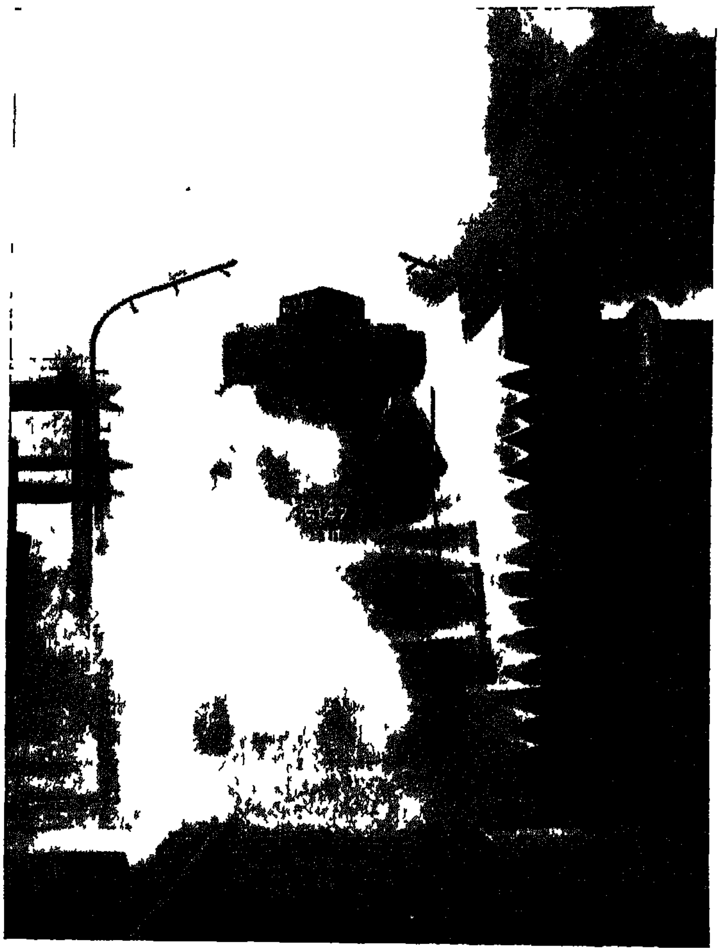
With its various component parts completed, comes the erection of the engine. The finished frame plates are set out on low trestles, and lines showing the position of the main parts are marked out on both sides. The frames are then mounted upright in adjustable forked stands and held together temporarily; brackets and stays are fixed, and then the cylinders are added. After a careful squaring-up and alignment, the frames are rigidly fixed to each other and the cylinders and other component parts permanently secured in proper position. Before the boiler is lowered on to the frames, as much as possible of the inside gear is fitted. At this stage the engine framework, complete with its boiler, is raised by an overhead crane, the wheels are run underneath and the locomotive carefully lowered on them. Valve and reversing gear are now fitted, together with the coupling and connecting rods. The bogie is next secured in position under the front of the locomotive, and springs and wheels are adjusted correctly. The engine is then painted and varnished and is ready for testing.

Locomotive tests are carried out either on the open track under working conditions, by means of a dynamometer-car attached between a locomotive and the train; or else the trial is made inside a weather-proof testing shed. Complementary to the latter are such plants as the L.M.S. Derby research laboratory in whose wind-tunnel the behaviour of models is observed. Air currents are sent through the tunnel at speeds up to 100 miles an hour; wind resistance is studied and data gathered as to how locomotives may be streamlined to the best advantage.

The mechanism of the dynamometer-car includes a special wheel with a hardened-steel tyre, which is ground to such a diameter

that exactly 440 revolutions are made for every mile of track covered This wheel, by appropriate linkage, records on a moving roll of paper the speed at which the train is travelling. Another device measures the draw-bar pull of the locomotive. In the dynamometer-car are also many other recording instruments and apparatus—some for analysing the gases in the smoke-box of the engine; some to record figures by which the total horse-power developed by the engine may be calculated; and others to record the expansion of the steam in the cylinders.

A more precise and accurate test of a locomotive can be made in the special shed with its array of instruments. There is a complete absence of weather variations that complicate an outdoor trial—such as side-winds which cause loss of power, and mist or rain which make the rails greasy. But testing plant of this type is very costly, and the only such establishment in Britain falls short of modern requirements. The U.S.A., Germany and France all possess large locomotive testing plants, and at Vitry, near Paris, is one of the most up-to-date testing stations in the world. It was to the Vitry plant that the famous L.N.E.R. express, "Cock o' the North," was sent in December, 1934, to undergo exhaustive tests.

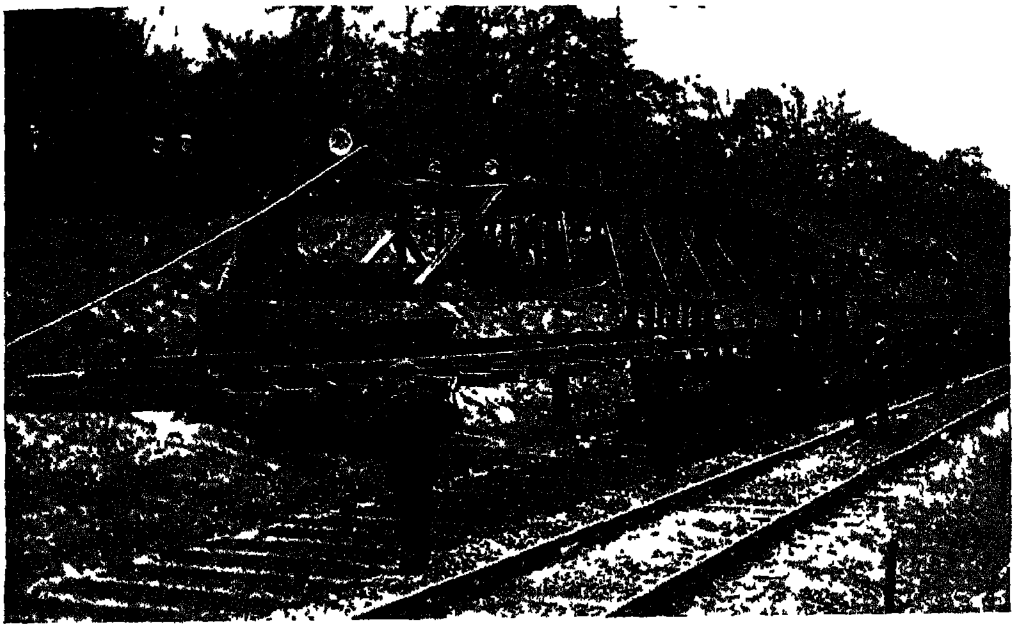


Courtesy of Canadian National Railways

Keeping locomotives and rolling-stock clean is one of the many problems dealt with by the great railway organizations. Here is an effective system of water-sprays in use on a big Canadian engine

The locomotive under test is run on to a platform whose floor comprises a series of rollers capable of being adjusted so that each of the locomotive wheels rests exactly on the centre of a roller. The engine draw-bar is connected to a hydraulic dynamometer anchored in concrete. Before use, quantities of fuel and water are carefully measured so that consumption over a given mileage can be observed. Steam is raised in the boiler, the engine is started and the wheels begin to revolve. Their movement turns the rollers, which are coupled to paddle-wheels encased in water-drums. The power of the engine is absorbed by the paddle action, which provides a load capable of being both varied and measured. The pull of the locomotive on the dynamometer is registered and other important data are ascertained. The giant locomotive—stationary though roaring "full out"—can be tested on the platform for hours.

There are other tests and these, though less spectacular, are just as important. Even before erection, all locomotive parts are rigorously tested at the building sheds; and all through the process of building and erection other necessary tests are carried out. After a locomotive has been passed out as satisfactory, and has gone into service, it is regularly inspected and tested to ensure that it is safe and efficient, and such necessary



tests continue up to the time that the engine is withdrawn from service.

Laying the Track

The preliminary stage in the making of a railroad is a careful survey of the provisional route and the selection of the substantive one. The labour necessary, and the cost, depend upon the nature of the country to be traversed. It has been said that the material excavated in making the railway between London and Birmingham would have sufficed to make a yard-wide path twelve inches thick around the globe!

After the survey the rail-bed is levelled, hills being tunnelled or pierced by cuttings, and valleys being filled. The engineer aims to arrange things so that whatever the contours of the country through which he is laying his railroad, the material excavated from tunnels and cuttings will approximately suffice to form his embankments. The early railways were constructed by manual labour, but nowadays the bulk of the excavation work is performed by mechanical scoops, diggers, graders, rooters and loaders. When

Courtesy of the L N E R. & Canadian National Rlys

Building the iron road at home and abroad. At work on the C.N.R. system in Canada and (*top*) the Morris track-layer, which picks up the old track and almost simultaneously replaces it with a new section

these mechanical navvies have completed the levelling of the rail-bed, the sleepers with their chairs are laid and the rails fitted. For laying one mile of double track there are required:

149 tons of rails	12,690 wooden screw ferrules
87 tons of chairs	4,230 wooden keys
$8\frac{3}{4}$ tons of chair-screws	2,115 sleepers
2 tons of fish-plates	4,230 felt pads
$7\frac{1}{2}$ cwt. of fish bolts	3,500 tons of ballast

Preparing the Sleepers

Most of the sleepers used in Britain are made of fir, and come from the Baltic countries. Each sleeper, which is 8 feet 6 inches to 9 feet long, 10 inches wide and 5 inches deep, has from four to five gallons of creosote forced into it under pressure. At the great railway depots, the sleepers are fitted with the chairs by automatic machinery, after which they are loaded into wagons and sent out ready for laying. Steel sleepers are being experimented with in this and other countries, and their success depends largely on their resistance to corrosion.

The rails used in Britain are much lighter than those used on many Continental and most American railroads. Some of the latter have standardized their main-line rails at 130, and even 150 lb. per yard against the general standard of 95 to $97\frac{1}{2}$ lb. per yard for Britain. The early types of steel rails varied from twenty-four to thirty feet long, but as better methods of handling were devised longer rails came into use, until to-day the average standard length in Britain is sixty feet. Most American rails range from thirty-three to thirty-nine feet; on the Continent rails of seventy-eight feet are quite common, whilst in Germany the thirty-metre rail (98 feet 4 inches) is often used.

Although many different types of joint have been devised, the rail joint still remains the weakest point of the track. This has brought about the practice, much in vogue in Germany, of welding rails together in long continuous lengths. On the Continent a flat-footed rail is largely in use, fastened directly to the sleepers without the intermediary of chairs. The type of rail used in Britain is known as the "bull-head rail"; it rests in cast-iron chairs weighing 46 lb. apiece.

When the chaired sleepers have been placed in position, the rail is inserted so that it rests on the chair-bed; between the web or waist of the rail and the outer jaw of each chair a key of either compressed teak or oak is driven tightly into position. Fish-plates and bolts are used to connect one length of rail to the next. Between the ends of adjacent rails the space of about a quarte of an inch is left to allow for the expansion and lengthening that takes place in hot weather.

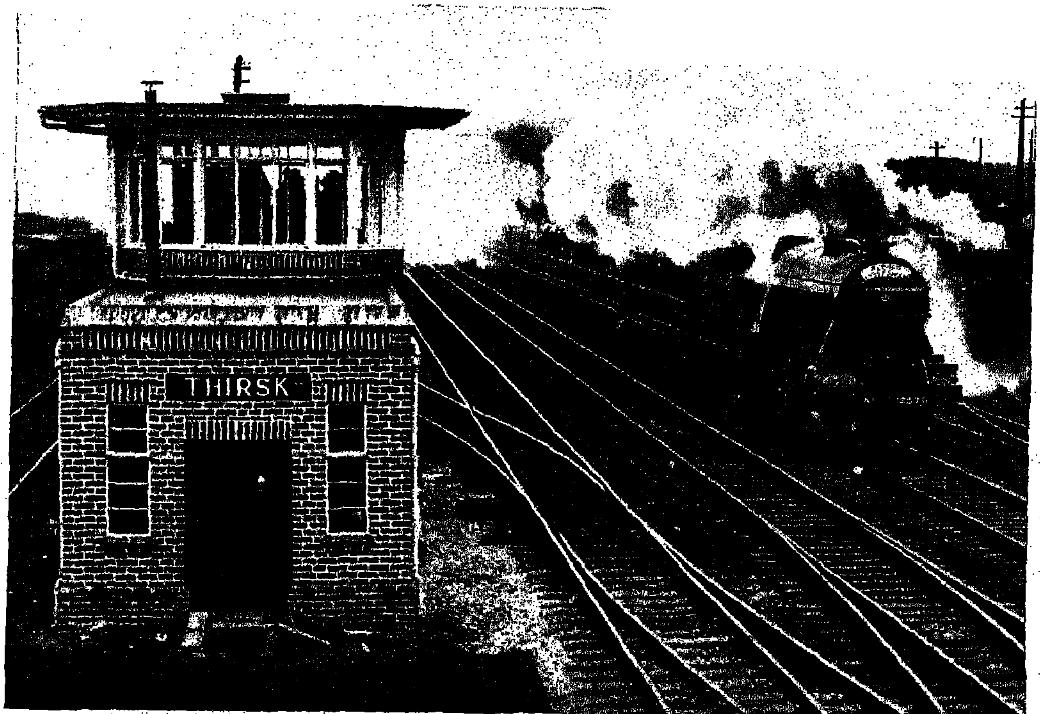
Track-laying machines, with rail-lifting and laying skids, are used to save time and labour. One type of track-layer lifts sections of the old track off the ballast and passes them back on a conveyer to wagons coupled behind. A trolley, so designed that it can move on rails along the whole length of the train, then brings forward a new track-section already assembled and lays it in place on the ballast. After a track has been laid, permanent-way inspectors test the road to satisfy themselves that the line is true to gauge and correct in level and alignment. The first locomotives passing over it usually proceed at a speed less than normal until the line has been practically tested. Passenger-expresses may be provided with a "track-recorder" which, during a test journey, produces a visible record of the oscillations of the train, by which the condition of the permanent way is indicated.

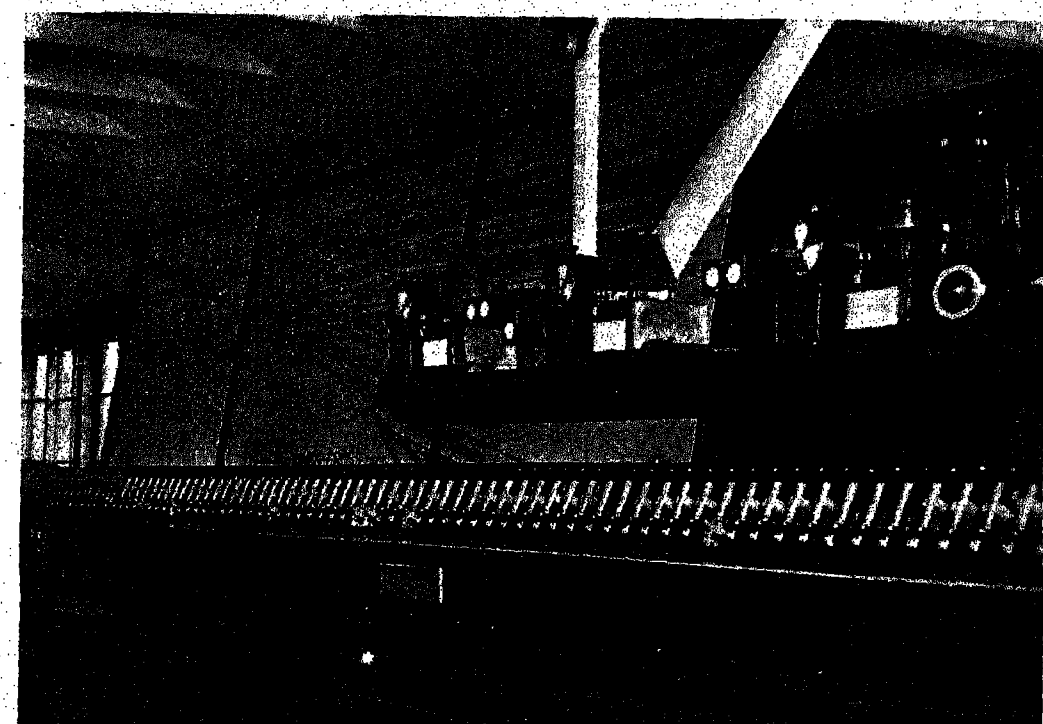
The standard width of permanent way in Britain and many other countries is 4 feet $8\frac{1}{2}$ inches. Brunel introduced a 7-feet gauge for the Great Western Railway, which was later converted to standard gauge.

Marvels of Railway Signalling

The first railway signalling was done by men standing at the side of the track, who used flags during the day and coloured lights at night. Directly a train had passed, a red flag or light was shown for a short period. This colour was then exchanged for green, later followed by white, showing that the line was now "clear." The time interval on which this early system relied was not found to be very satisfactory and after a few years the Block System was evolved. This system, an improved form of which operates on most railways of the world to-day, provided a space interval between trains following each other, by dividing the track into a series of consecutive block sections. No train was allowed to enter a block section already occupied by another train; nowadays a whole unoccupied section must lie between one train and the next.

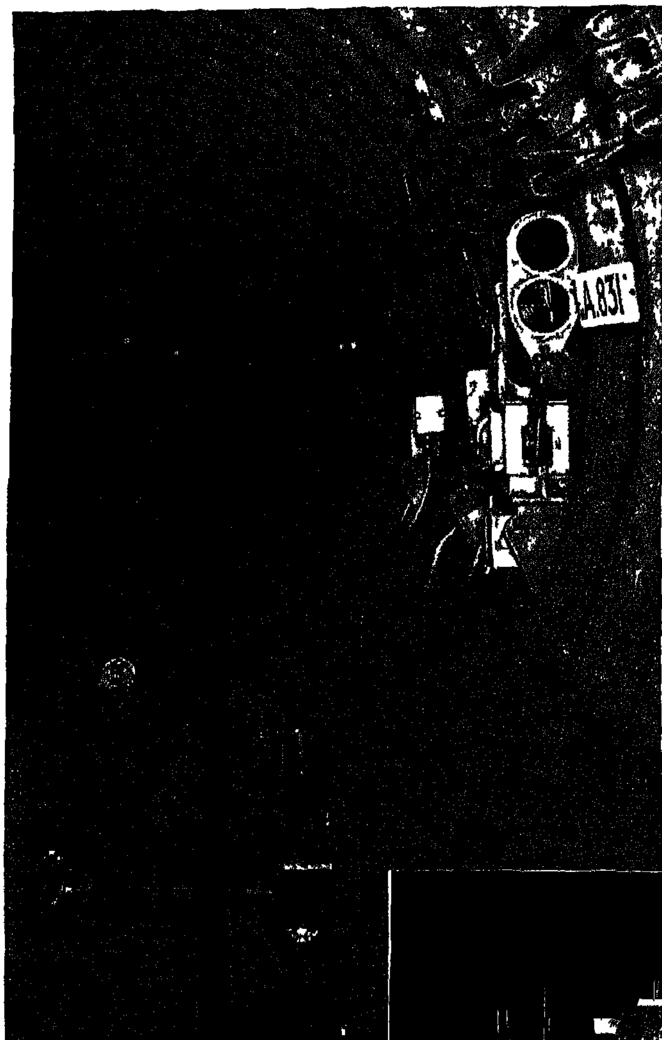
The first form of block system was operated in this country in 1839. By the early "forties" semaphore signalling was in





Courtesy of the L.N.E.R.

Electricity is being increasingly used to help the signalman in his important task. Interior of an all-electric signal-box at King's Cross, showing section of 232-lever frame. *Top:* The "Flying Scotsman" passing Thirsk signal-box, which operates about thirty miles of electrically controlled line, including points and automatic light signals

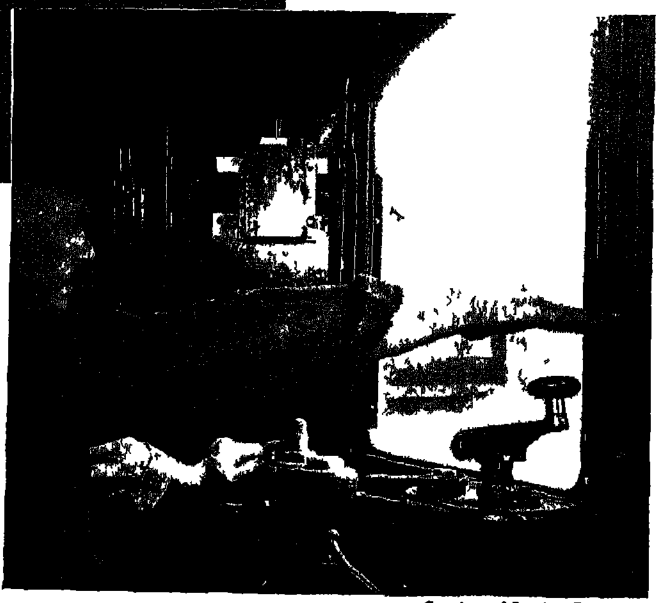


applied to-day, and only when the points have been correctly set can signals be given that would allow a train to traverse the points. In the quest for greater safety, various inventions were brought out from time to time; in some of these the train operated the signals by mechanical control as it entered or left a "block," and a form of completely automatic signalling was aimed at. This was ultimately made possible by the development of railway electrification, which required a system of signalling quicker than could be operated by the older manual form. The development of automatic signalling permitted the safe running of forty or more trains per hour, compared to the twenty or thirty trains possible under manual signalling.

In conjunction with the visual signal there is often a train-stop arm that rises beside the track and engages a trip-cock to operate the brakes if the driver should over-run a signal set at "danger."

use, utilizing three—later, in 1875, reduced to two—arm positions. At first these signals were set by hand from the post, but later a system of wires and pulleys manipulated from some nearby box were used to change the position of the arm. The electric telegraph was used to communicate information of train movements from one signal box to the next along the line.

In 1856 there was evolved a system whereby points and signals were interlocked, so that conflicting signals could not be given. Greatly extended and elaborated, this system is still



Courtesy of London Transport

Emergency safety devices on London's tube railways. The "Dead Man's Handle" which automatically stops a train when released by the driver, and (*top*) tunnel train stop which performs a similar function when the light signal is over-run

A separate development was power-signalling, in which the operator was relieved of the physical labour of moving the levers, rods, chains and signal arms. By means of quite tiny levers he now puts in motion electrical and pneumatic machinery that sets the actual signals and moves the points. In train-operated systems, the track is split up into a number of electric circuits and the train, entering or leaving a section, switches on or off current to raise the semaphore arm or allow it to fall, as the case may be. Thus the arm falls by its weight to the horizontal or "danger" position, and is raised by means of electric power to the sloping or "clear" position. In addition to the semaphore, light-signals are greatly used even for daylight working. Owing to the hoods and special lenses with which they are provided, they can be clearly distinguished from a distance. The use of colour-light signals during periods of bad visibility of foggy weather has greatly reduced train delays. Reverting to the older practice, three-position or three-colour signalling has come into extensive use again.

The tracks at Cannon Street Station, London—over which 460 trains carrying 67,000 people are run daily—are entirely controlled by colour-light signals.

The Automatic Train Control System

A system of automatic train control has been installed over 2,190 miles of the G.W.R. main line in Britain, and other railways have experiments in hand with similar systems.

The operating agent in the G.W.R. system is an electrified ramp laid between the running rails opposite the signal post. A contactor, depending downwards from the engine, slides along this ramp and puts in motion mechanism in the cab to indicate the state of the nearby semaphore. The ramp is electrified when the signal is set at "clear." Directly a contrary signal is given, the electric current to the ramp is shut off.

In Britain the chief enemy to the smooth working of a railway's schedule is fog, which entirely disorganizes the working of trains. To warn drivers audibly when the distant signal is at danger, detonator-caps are laid on the rail. These are small circular metal cases, containing gunpowder and fitted with caps, which are attached to the rail by means of lead clips. Detonators are always put down in pairs, for even if one should fail to explode, the other is hardly likely to misfire. The impact of the wheels fires the detonator, and the driver, hearing the explosion, reduces speed and prepares to stop at the next signal. At one time all detonators were laid individually by hand, but machines are now used for the purpose on some lines. The apparatus is worked by the signalman from the cabin by means of a lever. Other railways use detonator laying machines which enable a "fog-man" to put detonators on two or more sets of rails without crossing the intermediate lines. In a year of very bad fog a single railway company in Britain may use as many as 500,000 detonators.

Courtesy of the Czechoslovak Travel Bureau

Terminal station of the cable railway at Janske Lazne in Czechoslovakia

Aerial Ropeways and Rack Railways

Aerial ropeways were used for transporting goods or materials long before they were adopted for passenger carrying. In mountainous regions they may provide practically the only quick means of transport. An aerial passenger ropeway was constructed in 1912, in the South Tyrol between Lana and San Vigilio. It was so successful that before long passenger ropeways were built in many other mountainous districts. So efficient did aerial railways prove that Italy, during the Great War, built 1,200 miles of ropeways

on her Alpine front for the transport of troops.

There are two principal types of aerial ropeway. In the single-cable system an endless travelling cable supports and moves the carriers. Although simple and economical, this system is limited in capacity to conveying a maximum of only some 150 tons an hour. The greatest distance covered on any one section of a mono-cable ropeway is about four miles. The longest aerial ropeway of this sort is at Dorada, in the State of Colombia, South America. It is forty-seven miles in length and the line is divided into fifteen sections. Its capacity, however, is quite low, being only some twenty tons an hour; although used mainly for the conveyance of coffee, it is sometimes utilized for passenger traffic.

In the two-cable system two ropes are used, one of which is fixed and carries the load, while the other is the hauling rope. To the hauling rope the carrier is attached by a special coupling device. Mainly because it is far safer most passenger aerial railways use the two-cable system.

Compared in outlay to that of a railroad, with its giant locomotives, its rolling stock and its permanent way, the cost of constructing an aerial ropeway is trifling. All that is required are several steel towers, a few miles of steel cable, two cage-like cars and—the most expensive item of all—the driving machinery for winding in the cable. Once installed, the maintenance costs are very low.

On a passenger ropeway the carriages depart from the opposite terminal stations at the same moment, pass each other midway on the cable tracks and arrive at their destinations simultaneously. The principal brake system used is an automatic device, attached to the carriage, which grips the carrying cable and brings the carriage to a standstill. The seating capacity of these carriages varies from twenty-four to thirty-six passengers.

Ropeways of the World

Austria possesses ten rope railways, one of the most notable being that which ascends the Feuerkogel Mountains. It carries passengers from the banks of the Traunsee Lake to a height of 5,314 feet above sea-level. Another, in Carinthia, ascends the Kanzel Mountains to a height of 4,920 feet. Yet a third, greatly patronized by enthusiastic skiers, carries passengers from the valley town of Mariazell, 4,155 feet up into the snow-covered Burger Alps. The ropeway, commencing at Eisach, ascends the Kohlerer Mountain in the Austrian Tyrol for a distance of 5,250 feet; there are twelve steel towers to support the cables, which are one and three-quarter inches in diameter. The time taken to complete the journey is thirteen minutes.

The upper terminal of the Monte Sises-Sestrières Pass passenger ropeway in Northern Italy is built in two sections with an intermediate station, the topmost station being 8,200 feet above sea-level. Only five minutes are taken by the passenger ropeway linking Cape Town to the top of Table Mountain to achieve the 2,300 feet climb. The Bad Reichenhall line in the Bavarian Alps is three miles in length, and the rise of 3,160 feet is accomplished in nine minutes. Spain possesses several aerial ropeways, used both for carrying passengers and the transport of goods; but the majority of the European cableways are situated in the Alps and the mountainous districts of Central Europe, where under the two-cable system individual loads up to twenty tons can be raised and lowered down gradients as steep as one in one-and-a-half.

Mountain Rack Railways

Mountain railways, wherever possible, are built in great sweeping spirals so that the locomotives may climb the track by the easiest gradients. A good example of such track lay-out is that of the Bernina Railway, which runs from Tirano in Italy to St. Moritz in Switzerland. When, in course of construction, it was found that the track had to rise to a height of 7,315 feet at one point from a height of 3,315 feet only six miles away, a spiral lay-out was adopted and a railway built with a gradient of one in fourteen. This gradient is one of the steepest in the world to be achieved solely by adhesion of normal train-wheels to the rails.

But gradients steeper than this are to be met with, on which normal adhesion fails. In such circumstances if a line is to be built at all the adhesion between the wheels and the track must be increased. The more common method of achieving this is by means of a "rack-rail," the teeth of which are engaged by a power-driven pinion-wheel on the locomotive. The idea was first patented in 1811 by John Blenkinsop, an Englishman, for use in hauling coal-wagons on a colliery track; but George Stephenson demonstrated that ordinary smooth rails and wheels provided *sufficient adhesion on the level.*

One of the first mountain rack railways

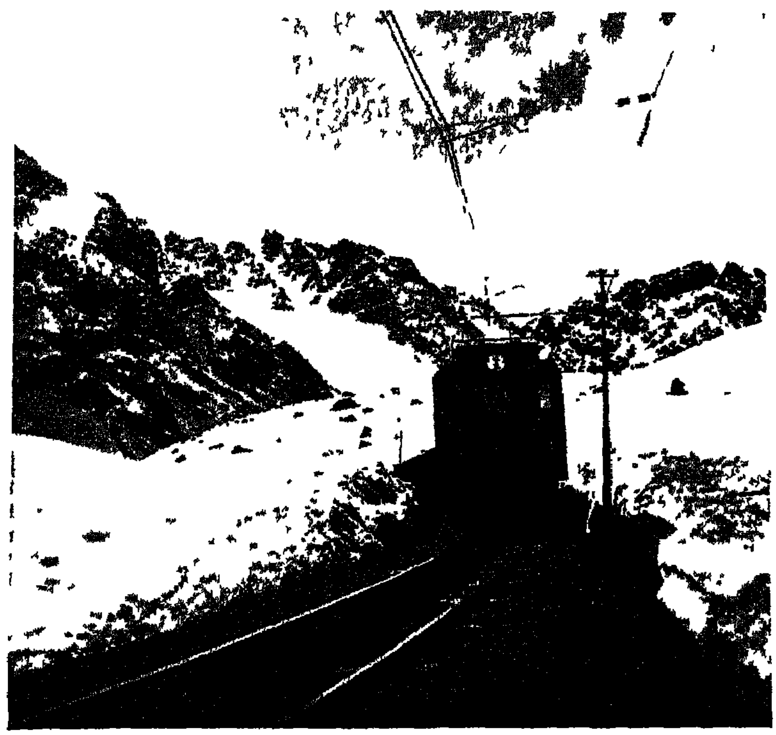
was built at Kahlenburg, near Vienna, in 1874. The maximum gradient on this line was one in ten, and a ladder type of rack, constructed in ten-feet lengths joined together with fish-plates, was bolted to the sleepers between the ordinary running rails. In 1882 R. Abt invented an improved type of rack, which two years later was incorporated in a line built at Blankenburg in the Hartz Mountains, and in 1894–96 Abt's system was utilized in the construction of a rack railway built up Mount Snowdon in Wales. The rack evolved by Abt had teeth cut in the edges of narrow rectangular bars, which, placed in pairs teeth uppermost, were set in chairs bolted to the sleepers. The double rack was engaged by a pair of stepped pinions on the locomotive. The Abt rack-system is used extensively in Switzerland to-day, many of the lines, such as that of the Visp-Zermatt route, being electrically operated. On this latter railway, gradients of one in eight are climbed at a speed of about ten miles per hour.

In the construction of a railway up the very steep Mount Pilatus, near Lucerne (1886–88), a double-rack system, invented by Dr. E. Locher, was used. It differed from Abt's device in that the rack teeth were placed sideways instead of upright, and that horizontal driving-wheels on the locomotive engaged the teeth on either side of the rack. The Pilatus Railway, which has a maximum gradient of almost one in two and an average gradient of one in three, rises to 5,347 feet and has a total length of two and three-quarter miles.

Another type, differing slightly from the three already mentioned, is the Fell system, used on the Rimutaka incline in the North Island, New Zealand. Here two locomotives, with five brake-vans, are used to haul a 260-ton train up gradients as steep as one in thirteen.

In Brazil, on the British-owned Leopoldina Railway, trains *en route* from Rio de Janeiro to Raul Soares have to be hauled by auxiliary rack-locomotives to a height of 2,600 feet over the Serra: this rise occurring in the short length of four miles of track. A rack railway in Greece, thirteen and a half miles long, climbs the gorge of the Bouraikos to Kalavryta, and the journey takes approximately two hours.

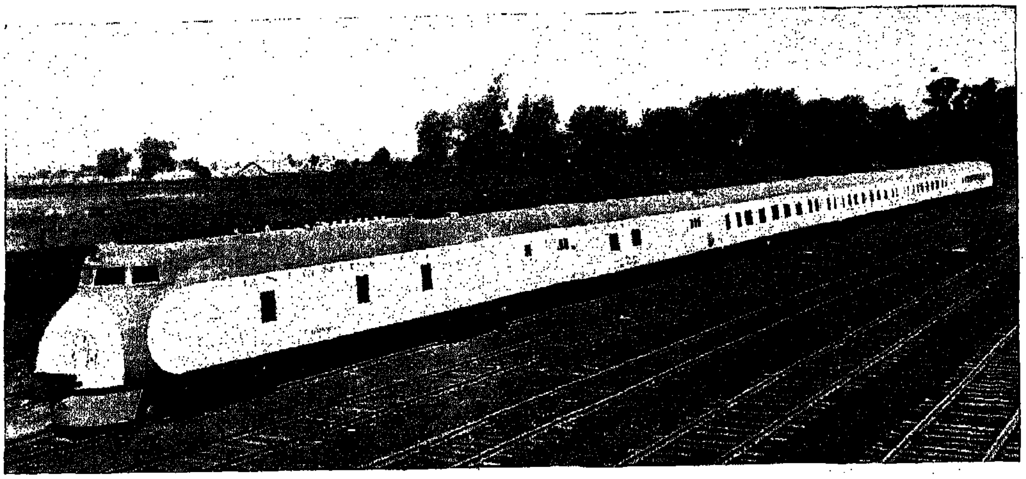
On the Transandine Railway which crosses the mountain range of the Andes from Chile to the Argentine, powerful tank locomotives are used, which are equipped for rack and pinion working as well as for running by normal adhesion. The maximum gradient on the adhesion section is limited to one in forty. As the gradients grow steeper so the rack sections of the route appear, and in a hundred miles of railroad the trains are raised almost 8,000 feet. Allowing for the steepness of the ascent the travelling is remarkably fast, electric rack-locomotives drawing a train of 150 tons at a speed of nine and a half miles per hour over gradients of one in twelve-and-a-half.



Crossing the snows of the Andes by electric train—near Portillo, on a rack section of the Transandine Railway between Chile and the Argentine

Streamlined Speeders of the Iron Road

In the last few years much theory has been elaborated and a considerable amount of

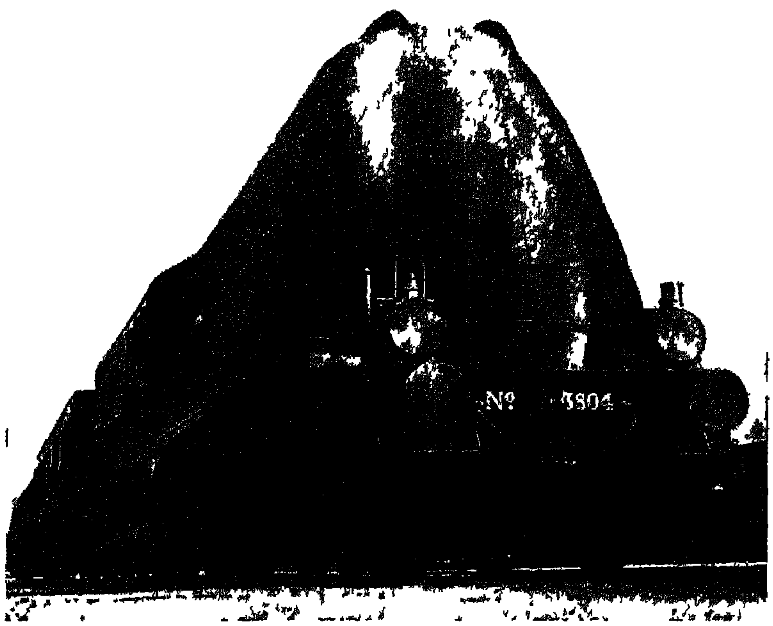


Streamlined record-breakers of the Old and New Worlds

The L.N.E.R. "Silver Jubilee" express which travels from London to Newcastle and back—536½ miles—at an average speed of 67·1 m.p.h. *Top*: The Union Pacific 6-car Diesel-engined train, which takes thirty-nine hours to complete the run from Chicago to Los Angeles

both experimental work and testing have been done with regard to streamlining not only of locomotives but of entire trains. These tests and experiments have shown that "streamlining" the casing of a locomotive, so as to lessen air-resistance, makes for increased speed and for greater economy in fuel consumption. Since air-resistance increases as the square of the speed, streamlining is obviously of far greater advantage where high speeds are concerned; figures have been given which suggest that at a speed of 100 miles per hour one-third of the air-resistance can be eliminated by careful streamlining.

Many original experiments have been performed in wind-tunnels where wooden locomotive models are suspended in a strong airflow and the effect on them measured by delicate instruments. The outcome of this research has led to the providing of streamlined casings on many locomotives, some being enclosed even down to rail-level. A great deal of this pioneer work has been done abroad, in America and on the European continent, but British railways, too, are well in touch with the work.



Streamlining on the Continent—a new locomotive on the Dutch Railways starting on a test run from Amsterdam

Early in 1935 the Great Western Railway produced two locomotives having bullet-nosed smoke-box doors, pointed fronts to the cabs, and a casing over the cylinders and motion. But after several runs it was found necessary to remove this casing, since the motion tended to overheat when shut away from the cooling influence of the outer air. On September 27 of the same year the L.N.E.R. streamlined express "Silver Jubilee" made a demonstration run between King's Cross and Grantham, and created four world records, twice attaining a maximum speed of 112½ miles per hour; the whole train was streamlined from end to end. On this run the seven vehicles of the train had a gross weight of 230 tons, so that the feat of covering twenty-five miles of the journey at an average speed of 107 miles per hour was a splendid performance. Between the bogies of each coach a skirting reached to within ten inches of rail-level, and the coaches were joined one to another by panels of rubber sheeting.

The locomotive itself, named "Silver Link," resembles from the front a huge horizontal wedge. This type of streamlining has been found to be more advantageous than the vertical wedge type, previously used in France. Following this most successful trial run, three sister locomotives of the same design were arranged to be constructed. On September 30, 1935, the "Silver Jubilee" train entered into regular daily service between Newcastle and London, where her scheduled time to cover the double journey of 536·6 miles calls for an average speed of 67·1 miles per hour.

The Flying Hamburger

Before this German streamlined train was built, experiments with special models were made in the apparatus used for testing models of Zeppelins. The sharply-rounded ends of the train and the rounded skirting which comes almost to the rails were adopted as the result of these tests. Since the "Flying Hamburger" was designed to be electrically driven from power developed by two Diesel engines, there was no need for a

large projecting smoke-stack; a small pipe in the roof carries off the exhaust from the oil engines. After her preliminary run, this crack German streamlined train settled down to routine service between Berlin and Hamburg, a distance of 178 miles. The train carries 102 passengers and covers the journey at an average speed of just under 77 miles per hour, with a maximum speed of 100 miles per hour.

In all, a dozen German streamlined rail-cars are in service, covering regular journeys at a speed of 75 miles per hour and over. The Diesel-electric "Flying Cologner," which runs between Berlin and Hanover, does that journey at an average speed of 82·3 miles per hour. In 1935 a streamlined Borsig steam locomotive attained a speed of 119 miles per hour on a trial run, and covered 178 miles at 74 miles per hour; whilst yet another streamlined steam locomotive hauled a 250-ton train at speeds varying from 93 to 108 miles per hour.

American "Flyers"

In the United States streamlined trains have come into use on many long-distance services and have become immensely popular. On April 6, 1935, a streamlined Diesel train made a trial run between Chicago and St. Paul, a distance of 314 miles, in five hours thirty-five minutes, and a top speed of 104 miles per hour was claimed to have been reached. By the end of May a steam rival, the streamlined locomotive "Hiawatha," went into service. Hauling a six-car train which although empty weighed 340 tons, "Hiawatha" attained a speed of 73¾ miles per hour over 40 miles; and during a run of 410 miles, which included five stops, her average speed was 63·1 miles per hour.

The "City of Portland," streamlined express of the Union Pacific Railroad, was put on the Chicago–Portland route in 1935. Propelled by Diesel engines, this train hauls a six-car unit over the 2,272 miles of her journey, which includes the crossing of the Rockies, in 93¼ hours; the best steam service to cover the same distance takes nineteen hours longer.

In April, 1935, the "Comet," a streamlined Diesel-electric train of the New York, New Haven and Hartford Railroad, was tested over the track near Rhode Island. "Comet," which cost £50,000 to build, is unusually designed in that she has engines at either end operated simultaneously by a master-control; this obviates turning the train at the end of every trip. Over a one-mile stretch, "Comet" attained 110·5 miles per hour. Her normal schedule includes a 43·8-mile run, covered in forty-four minutes.

Steam, Electricity or Oil?

For nearly a century the steam locomotive, using coal as fuel, held the field almost unchallenged. The last few years have seen the rise of various competitors notably the Diesel and the Diesel-electric types of train. Many of these trains have put up amazing performances both on trial and on subsequent service, averaging often a mile or more a minute over long distances. But almost all such trains have the advantage not only of being streamlined but of having a smaller passenger capacity and of being lighter in weight than the average steam train.

Points in favour of the Diesel engine are: that its fuel costs are in the region of a quarter of that of a steam engine, that it can attain a high speed very quickly, and that there is a considerable saving in weight and space since less fuel and no water supplies need be carried. In the Diesel-electric type of train, which is rapidly coming to the fore both in the U.S.A. and on the Continent, the oil engines drive an electric generator, the current from which goes to motors that turn the wheels. One contingency with such trains is that although the oil engines may be functioning correctly and there is nothing wrong with the electric machinery, frequent breakdowns are liable to occur unless the co-ordination between the two motive plants is perfect. In 1934 a number of rail-cars had to be withdrawn from service on the Netherland railways for such a reason after a few months.

Besides the Diesels, that burn crude oil, other internal-combustion-engined plants have come into use for hauling trains. France seems to be particularly interested in the petrol-engined rail-car; a streamlined Bugatti train on the Paris–Vichy route covers the distance of 226¾ miles in 223 minutes. The fuel used for the four 200 horse-power engines in this case is a mixture of petrol, benzol and alcohol. Smaller rail-cars of this type have been tried out in Britain: one, of French design, carrying fifty-six passengers at a speed of 56 to 60 miles per hour, has a fuel consumption of only one gallon of petrol per six miles.

A further challenge to steam has been offered by the electrification of much track, not only in this country but on the Continent and elsewhere. The largest suburban electrification scheme in the world is being carried

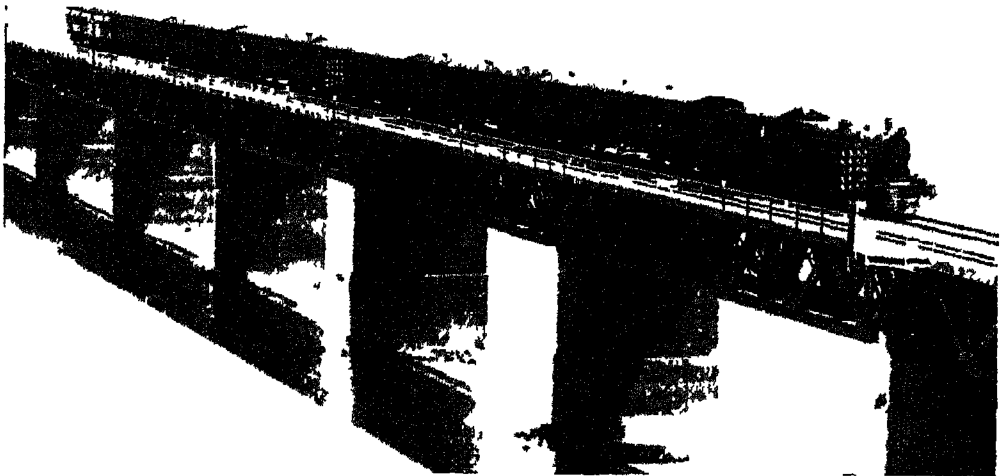
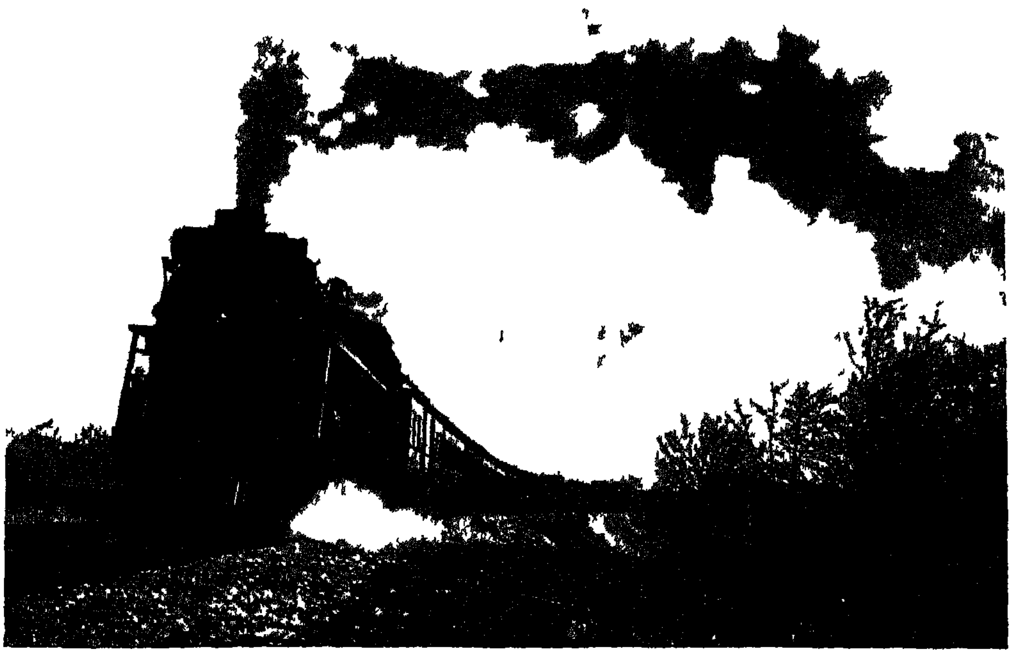


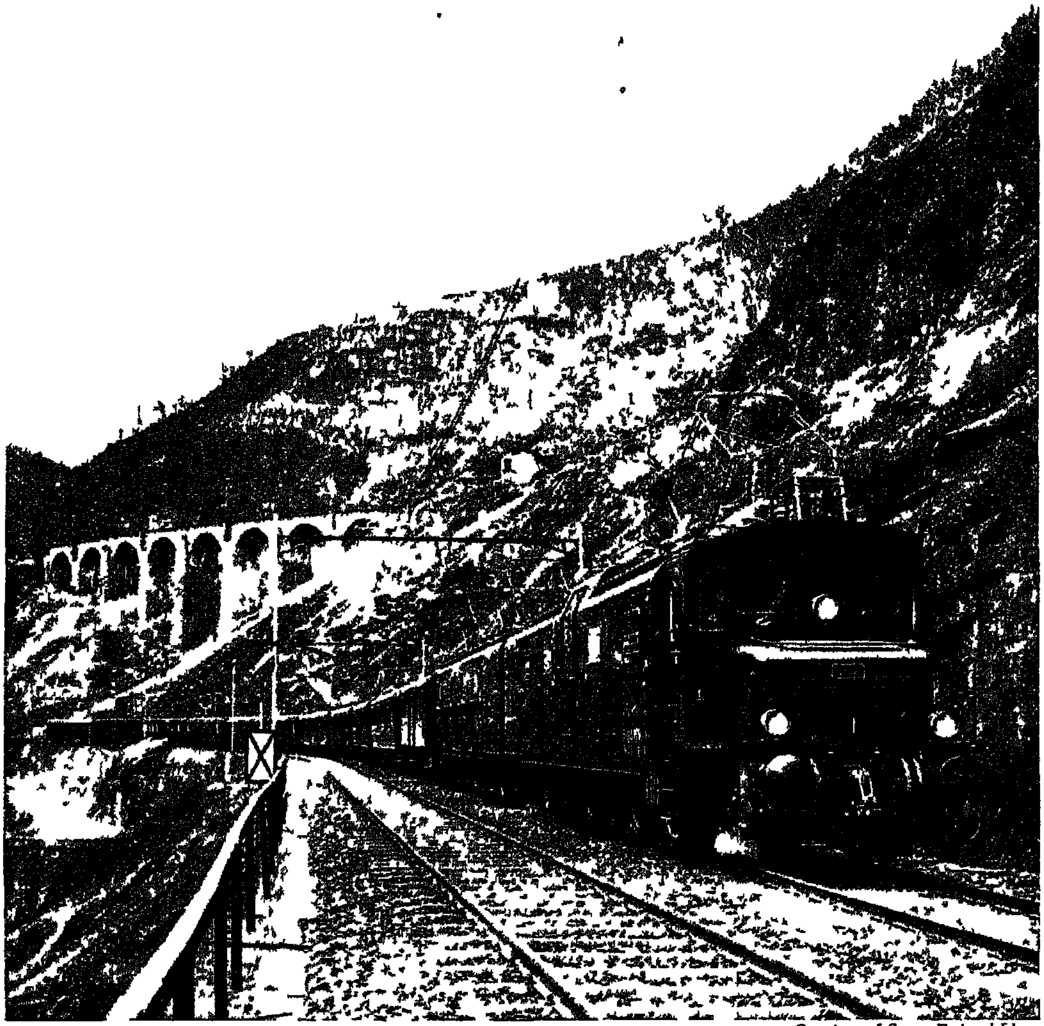
Photo · W. Stokes



Courtesy of Canadian National Railways

Famous expresses of two continents

"The International Limited," which runs from Montreal to Chicago (849 miles) in 17¾ hours; and (*top*) the Great Indian Peninsular Mail Train, which takes twenty-six hours from Lucknow to Bombay (880 miles)



Courtesy of Swiss Federal Rlys

An international express hauled by electric power This huge 8,500 h p Swiss locomotive has a length of 111 feet and pulls its heavy load up numerous steep gradients on the mountain-section of the St Gotthard line It is here seen descending from the southern entrance of the famous tunnel *(See also illustration Chapter XXVI)*

out in the South of England When first outlined, this scheme was intended to have been worked on the overhead conductor system, but later the third-rail system was standardized Electrification, with its heavy initial outlay, is most serviceable in a densely peopled suburban area

Besides streamlining, efforts have been made in other directions to increase the efficiency of the steam locomotive In an effort to make greater use of the heat energy of the steam, "turbomotives" have been tried out, in which the locomotive is propelled by a turbine instead of the usual reciprocating engine Ljungstrom, a Swedish engineer, built a turbo-locomotive as long ago as 1921, and one constructed on his system in Britain in 1926 attained a speed of 76 miles per hour Not only was there a great saving in water consumption, but the engine only required about half as much fuel as an ordinary locomotive which, hauling a 331-ton train over a distance of 152 7 miles, averaged 69 8 miles per hour, with a top speed of 90 miles per hour Performances such as this show that the steam-locomotive is far from being put in the shade by its more modern rivals

The answer to the query that heads this section is that all three propellents have their use and justification in different fields, and the future is likely to see the parallel development of each to greater efficiency.

CHAPTER XIX
VOLCANOES—PAST AND PRESENT

"STUDY the volcanoes of the world, tabulate their revealed secrets, and in the sum total of that knowledge we shall have solved most of the mysteries of our earth." So, in effect, said the scientists of our grandfathers' day. But though geographer and geologist, daring mountaineer and chemist have ceaselessly probed and laid bare a thousand and one secrets, they still have much to discover. They can tell you that the highest active volcano of the entire planet is Cotopaxi in the South American Andes; that the volcano on Maui, one of the Hawaiian Islands, has the largest crater in the world; that even under the sea there are active volcanoes.

They will tell you of all the dust and ashes, lava and pumice, sulphur and salt, glass-like rocks and gases that pour from the volcanoes' fiery throats. But though earth still withholds a myriad secrets from Man, scarcely a day passes without some new fascinating discovery being made about the "fire-mountains" of the world.

Mountains that Awed Mankind

From earliest ages these fire-vomiting, smoking, death-dealing mountains have awed mankind. Many volcanoes have been worshipped for innumerable centuries—notably beautiful snow-clad Fujiyama in Japan and Mauna Loa in the Hawaiian Islands. Tennyson has written a poem, "Kapiolani" telling of how a daring chieftainess became a convert to Christianity and defied the volcano goddess Pele by climbing to the crater of Kilauea, Mauna Loa's neighbouring peak, scornfully to fling consecrated berries into the fiery lake below, thus shattering the power of Pele's priests.

Although a volcano is usually thought of as a mountain, it need not be one. Its main characteristic must be that it is a hole in the earth's crust through which heated matter, gases and vapours find their way to the surface. Such an opening is always found in some weak spot caused by the folding and upheaval of rocks in the early days of the world. There is a great belt of volcanoes around the Pacific basin, and here is found the greatest volcanic activity in the world. Frequently we hear of earthquake disasters in Japan, and it is because of the constant expectation of such occurrences that the Japanese build frail houses of bamboo and paper. Stone ones would be more dangerous in falling, more expensive to replace, and would not stand up to shocks so well.

When great masses of rock and cinders are thrown out of a volcanic hole they pile up around the vent, each successive outburst adding to previous deposits. Streams of molten lava also make their way down the slopes from the crater, sometimes to flow for miles over the lower ground, at others to be checked and pile up on the shoulders of the eminence. Thus a hill and eventually a mountain comes into existence. This mountain formation distinguishes a volcano from its four cousins: the geysers, hot springs, solfataras and fumaroles.

Geysers and hot springs spurt out hot water, steam and sometimes mud. The world's chief sources of this natural hot water supply are in Iceland, New Zealand and Yellowstone Park, U.S.A. These wonderful natural phenomena are described at length in Chapter XLI. Solfataras are volcanic holes or sometimes non-active volcanoes which constantly give off hot sulphur vapours. The most famous lies west of Naples, and has not been active as a volcano since 1198. Fumaroles are openings in volcanic regions which give off hot vapours. The hottest fumaroles reach a temperature of 500 degrees centigrade, while even the cooler ones are rarely less than 100 degrees centigrade, the boiling-point of water.

Valley of Ten Thousand Smokes

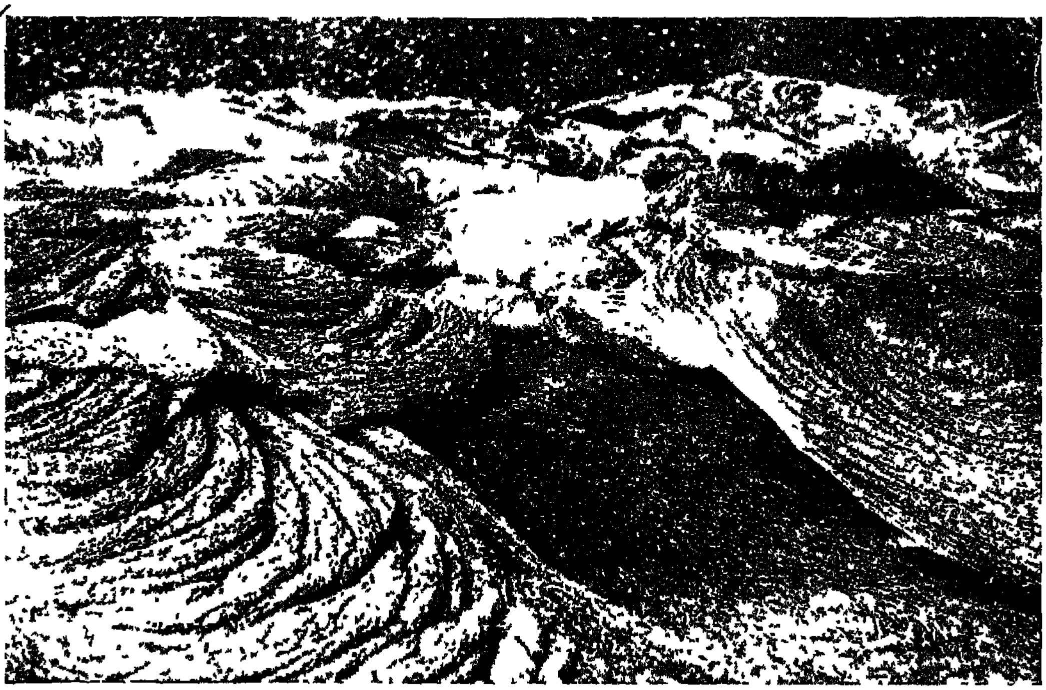
In 1912 there occurred in Alaska one of the greatest volcanic eruptions of our own time. The top of Mount Katmai, a supposedly extinct volcano, was entirely blown off, and in a valley to the north-west enormous numbers of tiny volcanic vents or fumaroles opened. Since then the district has been named the Valley of Ten Thousand Smokes and proclaimed a national monument.

The ejection of scalding steam and vapour is the common feature of all types of volcanic eruption. It was noted by the Roman writer, Pliny the Younger, as long ago as A.D. 79, when describing the eruption of Mount Vesuvius in which his uncle, Pliny

the Elder, had lost his life He tells of the enormous column of vapour and dust a mile or two high which rose from the crater. This column then spread out into a vast canopy of cloud, the whole resembling "a pine tree appendage" with trunk and spreading branches. The highest recorded smoke column preceding a violent eruption was at Krakatoa, in 1883, when the steam and dust reached many miles into the skies.

Such a great column of steam cannot stay indefinitely suspended in air, especially as the upper atmosphere becomes colder and colder. Consequently it soon condenses to crust. Further eruptions caused layer upon layer to be deposited on the site, until now archæologists have to cut through eighty feet to reveal the marvellous ruins of the ancient pleasure resort of the Romans. Pompeii, a neighbouring city, was destroyed in a totally different manner, being obliterated by a rain of hot ash that lasted for days on end, suffocating the inhabitants and besprinkling the city with a dust of death.

Thus it is not only the fiery lava and the poisonous vapours that prove so destructive. After any volcanic eruption the country for



Coiling in strange whorls and patterns—an evil-looking mass of molten lava thrown forth from Vesuvius

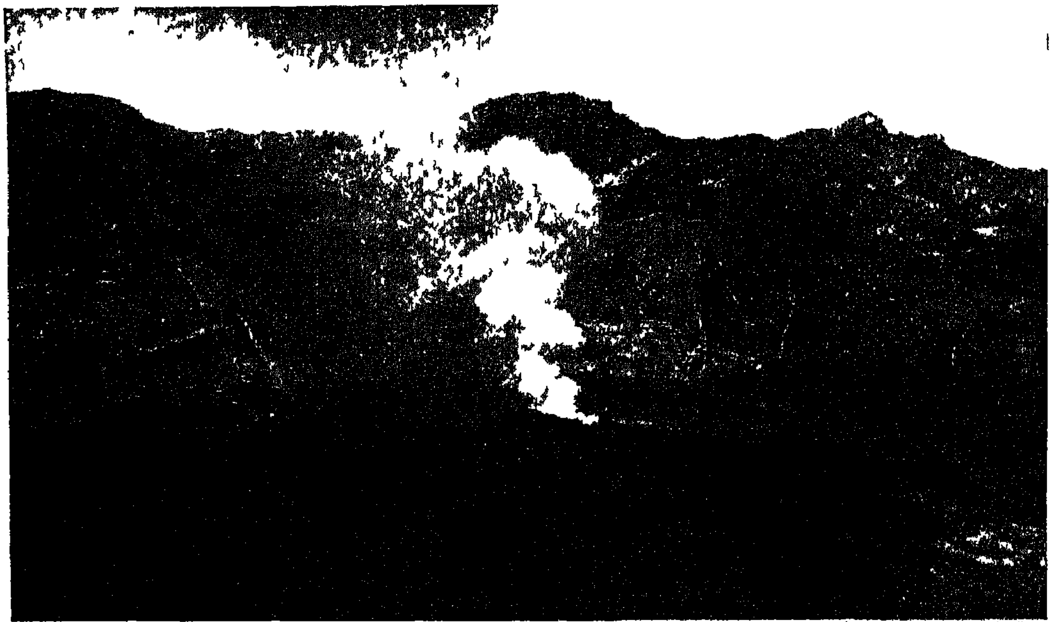
rain, which falls and mixes with the ashes and loose material to form a kind of hot mud, which rushes down the mountain side, spreading far and wide. Sometimes it is enough for the steam merely to meet the cool air as it rises to the lip of the crater. There it condenses and forms a mud with the hot ash, rock fragments and cinders. Up the crater wells a fiery flood of molten rock: this is lava. Down the mountain side pours the fiery stream, sometimes at forty or fifty miles an hour, blotting out whole villages in its relentless march.

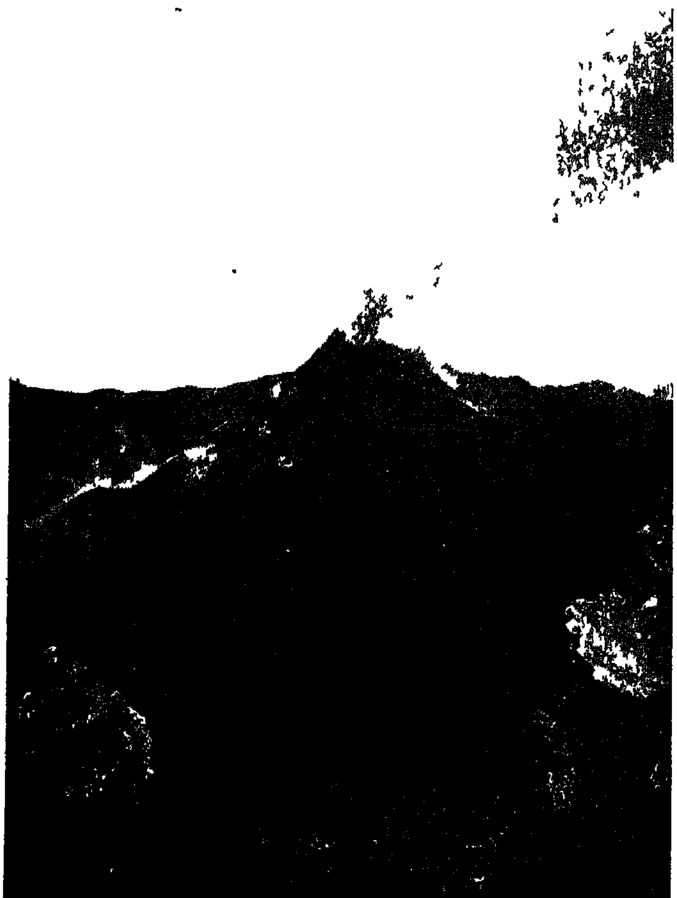
Herculaneum was buried beneath the fiery flood which Pliny observed in A.D. 79, when Vesuvius erupted. As the lava cooled it completely sealed the city beneath a hard miles around is usually covered with a fine greyish ash, such as that which buried Pompeii. Closed windows and doors are of no avail. The fine ash insinuates itself into the tiniest crevice. Its accumulated weight will crush roofs and whole buildings.

Lava, on cooling, takes many strange forms and often beautiful shapes. The lower layers cool more quickly and form obsidian, a volcanic glass. Most familiar is the pumice stone, a porous froth-like material. In Hawaii it is black, in the South American Andes yellow or brown. But the grey pumice stone we use in our bathrooms comes from the Lipari Islands in the Mediterranean. Artists, vinegar makers and furniture manufacturers are the chief users of this volcanic

Photos A W. Exell and (top) W. F. Taylor

Curious geometrical shapes formed by volcanic rock are to be found in many places where lava has flowed in past ages. Basalt formations on the coast of S. Tomé in the Gulf of Guinea, and (top) "The Honeycomb," part of the well-known Giant's Causeway, in co. Antrim, Ireland





Bottom Photo Courtesy of E.N.I.I.

Still active and smouldering: the cone inside the crater of Vesuvius

"waste." Iceland, Hungary, Nevada, Teneriffe and New Zealand all yield good commercial pumice.

Strange rock formations and beautiful volcanic caverns have been produced by lava flows in past ages. An excellent example is the Giant's Causeway, a natural pier on the north coast of County Antrim in Ireland. There are actually three causeways, the Little, Middle, and Grand, all composed of six-sided pillars of basaltic rock, packed closely together and so regular that they appear almost to be the work of Man and not of Nature. The pillars are about fifteen to twenty inches in diameter and rise in places to twenty feet high. The Grand Causeway is forty feet broad in its widest part. The neighbouring cliffs also have many similar columns.

Across the sea, forming one of the Inner Hebrides of Scotland, is the island of Staffa, largely built of the same columnar basalt. The

Giant's Causeway and Staffa were once united and formed part of the same volcanic belt. The island has several beautiful caves lined with some handsome columns. In Fingal's Cave, the most famous and most visited, the coloured pillars on the western side rise to thirty-six feet in height. More is said about caves in Chapter XIII.

Daintier forms are found in the lava "trees" of Kilauea, and in the delicate "Pele's Hair," fine strands of rock reputed in legend to be the tresses of the Hawaiian volcano-goddess.

So much for the substances within the active volcanoes. But how is it that the lava streams are not continuous, and the ejections of ash and rock are not constant? In some parts of the world—for example, in the Deccan Peninsula of India, in Idaho and Washington states, U.S.A., and in Northern Ireland—there was in ancient geological ages a ceaseless outpouring of lava from open fissures in the ground. The molten matter welled up and spread in a vast lake, gradually solidifying to an extremely hard rock. The great fields of black basalt in Iceland were created in this fashion.

In a comparatively young volcano, surrounded by a high rim of its own debris, the lava and ash are able to escape only at long and comparatively infrequent intervals. In the case of Mount Mokuaweoweo, in Hawaii, the boiling mass must rise 600 feet before it can pour over the crater edge—a veritable safety wall that protects the light-hearted inhabitants of the villages below. This great crater or hollow is formed and kept open by the constant explosion of vapours and gases. When the explosions cease the volcano becomes dormant, the lava solidifies, and later the walls crumble to fill in the cavity.

If a renewed outburst occurs, the floor of the crater either cracks open or the pent-up mass forces its way to some weak spot in the side of the mountain. A secondary or lateral crater is thus formed—the original being known as a terminal. Picturesque Edinburgh Castle, standing high above the streets of the Scottish capital, is built on the lava core of a long-extinct terminal crater. The highest volcano in Europe, Mount Etna in Sicily, is dotted all over with some 200 small lateral craters or cinder cones.

As such a great area of the earth's surface lies below the ocean, it is quite reasonable to expect that volcanic eruptions occur also on the sea floor. Investigation of great tidal waves, of the sudden appearance of new

Photo: E. Baena, Teneriffe

A landmark for shipping for many miles around—the famous El Pico de Teide on the island of Teneriffe, a dormant volcano with a crater 70 feet deep

islands and the equally sudden submergence of others, has led to the belief that undersea eruptions are by no means uncommon, particularly in the Pacific.

Christmas Island, in the Indian Ocean, is an example of a submarine mountain which has been built up during long ages from continued accumulations of erupted debris upon the sea floor. Nearer home, both Mounts Etna and Vesuvius began as volcanoes on the bed of the ocean, the accumulated debris and lava rising gradually higher and higher until the crater was far above the water.

Sometimes islands thus formed have only a short life. One of the best examples of such a temporary island was recorded in 1831, the new formation occurring in the Mediterranean between Sicily and North Africa, in water 100 fathoms deep. After one great disturbance, when the sea became violently agitated, throwing up great fountains of water, steam and debris, with shoals of dead fish, an accumulation of volcanic cinder and ash formed an island 200 feet high at one point. Unfortunately the new Graham's Island, or Ile Julie, could not for long withstand the continual wearing action of the waves. At the end of three months it was reduced to a mere shoal, now called Graham's Reef. In 1811 another such temporary volcanic island, which was named Sabrina, was thrown up off St. Michaels in the Azores.

It was Vulcan, the old Roman God of Fire, who gave his name to volcanoes; and, as far as can be ascertained, the first "fire mountain" to be called a volcano was Mount Etna in Sicily. Although there still remains in the Mediterranean a group of active volcanoes—Vesuvius, the Lipari Islands, with Stromboli and Vulcano, Graham's Reef and Etna itself—Europe is a continent mainly of extinct volcanoes.

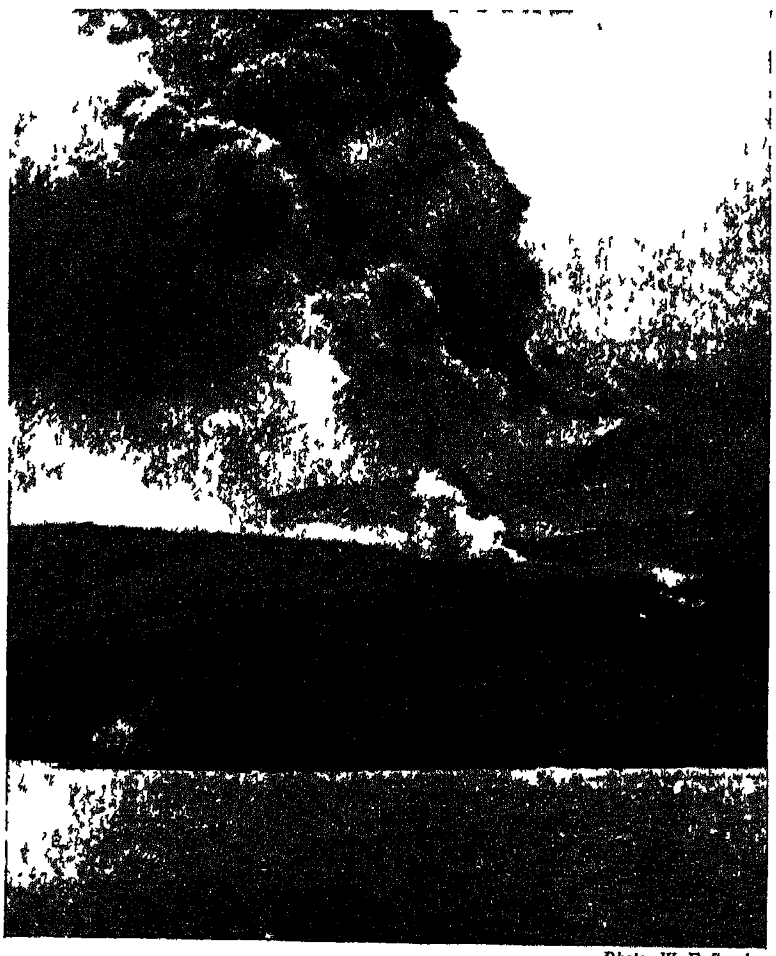


Photo W. F. Taylor

The appalling disaster on the Island of Martinique in 1902, when Mt. Pelée burst into eruption, causing the death of 30,000 people. This remarkable photograph shows part of the actual outbreak near Rivière Blanche

The Auvergne range in France, Bohemia in mid-Europe, parts of Great Britain, and the Italian Euganean and Alban Hills are all cold and silent volcanic ridges. Even the volcano islands of the Atlantic chain — the Azores, Canaries, Cape Verde group, Ascension and St. Helena—are very feeble or have lost all activity. Not since the reign of our King Henry VIII has there been an eruption in the Azores. Then the whole of Villa Franca, the capital, was wiped out in a great lava deluge.

In the reign of Queen Anne a lateral cone in the side of El Pitou, in Teneriffe, discharged a great stream of lava which almost filled up the harbour of Garachico. But

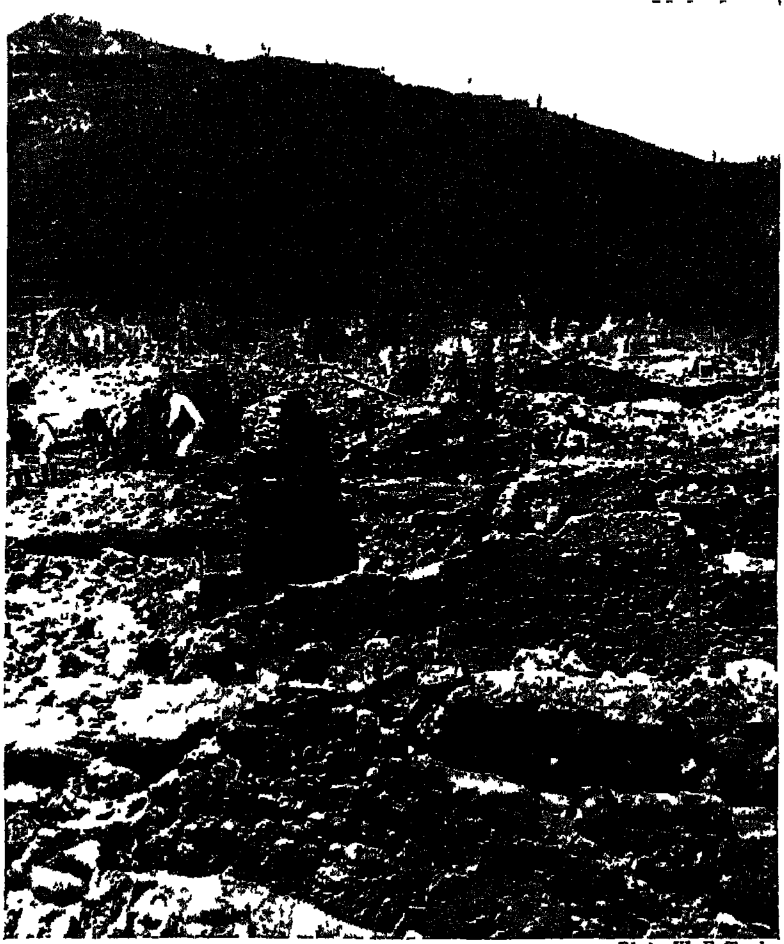


Photo: W. F. Taylor

Among the ruins of St. Pierre, covered with volcanic ash to a depth of several feet after the great eruption of Mt. Pelée, in 1902. Three days elapsed before rescuers could approach the devastated town

nowadays the big craters there just idly puff up a little steam and some sulphur vapour. Their day of awe-inspiring majesty is over.

Iceland continues the Atlantic volcano ring. But though to-day the greater amount of ejected matter comes from geysers and earth fissures, Dr. T. Thoroddsen, an Iceland geologist, states that there are about 130 volcanoes on the island; twenty-five to thirty have been in eruption during the historic period.

On the other side of the Atlantic there is an interesting region in the West Indies. There a string of islands, the Lesser Antilles, sweeps in a curve across the east end of the Caribbean Sea. They are subject to frequent earthquakes and abound with volcanoes, solfataras and hot springs. These islands are the highest peaks of an enormous fold of under-sea mountains. Frequent disasters, involving the loss of thousands of lives, have happened, particularly on the island of Martinique, where Mount Pelée (not to be confused with Pele the volcano-goddess of Hawaii) fumes and rumbles year after year.

It was in 1902 that the busy town of St. Pierre, lying close to the base of this volcano, was stricken by a disaster in which 30,000 people perished. Although a great part of Mount Pelée's slopes were turned into a wilderness by successive flows of lava, and in 1843 alone there had been 200 earth shocks, the volcano was thought to have become dormant after a slight eruption in 1851. For fifty years all was still. Business prospered in St. Pierre and the owner of the largest sugar plantations on the lower slopes had just erected a new sugar-refining plant.

Suddenly the giant awoke from his slumbers. Mont Pelée began to rumble, then to roar, hurling great masses of cinders over the countryside. Two days after the first warnings, on May 5, 1902, a boiling stream of lava and mud flowed over the crater lip and in three minutes made its way five miles along a river bed to the sea. In its path lay the new sugar refinery. A mud stream twenty feet high engulfed the whole place in a few seconds, killing twenty-three persons before they had time to realize what was happening. The boiling torrent forced back the sea itself for 100 yards. Terrified people rushed hither and thither in mad confusion.

For two or three days the smoke pall rose higher, swelling out over the angry crater. It swayed and hung like a giant curtain,

darkening everything around for miles. Detonations like gunfire added further to the terror of those awful days. The Governor, seeing how difficult it was to manage the terrified crowds in the streets, drew a cordon round the city, but in doing so he signed the death warrant of many who might have escaped, for at about nine o'clock next morning Pelée hurled high into the air the great purple curtain of dust and gas, and with a roar flung a hail of white-hot lava and flaming cinders over town and sea.

Nothing could escape the pitiless rain of fire. Thirty thousand people perished, and from the burning town only one man escaped alive. He was a prisoner in the jail, and he was saved by the substantial walls of the prison house. Eighteen ships in the harbour caught fire. All but one were a living hell in a few minutes and most of the crews perished. One vessel had steam up and put to sea. Even so, it carried ten charred corpses on its decks beneath a pall of ash.

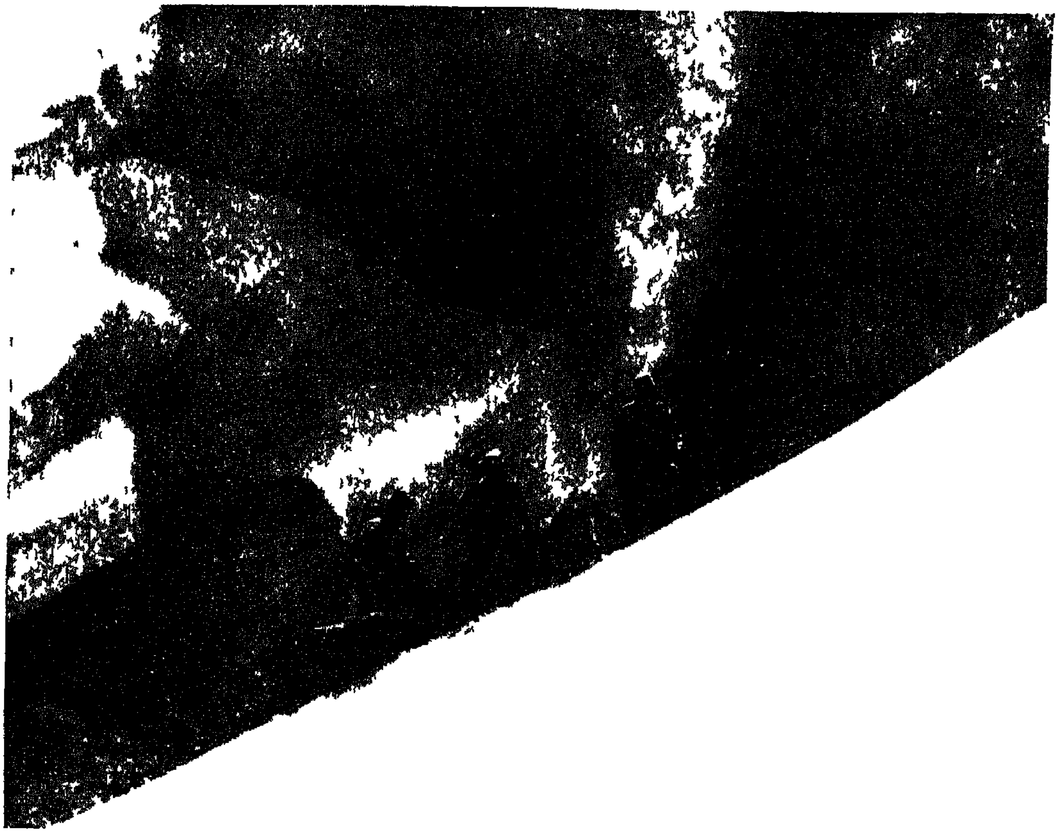
Three days passed before rescuers dared to enter burning St. Pierre. Cinders were piled yards high in the streets in the centre of the town. Many bodies were lying on their faces with hands pressed over mouth and nose. The asphyxiating sulphur smoke had had a deadly effect, and had proved the final terror for those who escaped the hail of fire One strange phenomenon that occurred during the disaster was the growth of a great spire of glassy lava at the volcano's top. Rapid belchings of lava had poured forth in such quick succession that the molten rock could not escape down the slopes fast enough. It piled higher and higher, solidified and grew into a towering pinnacle a mile high.

Fiery Mountains of the Americas

In the United States there are but few active volcanoes to-day, though many have become extinct in comparatively recent geological times An eruption occurred in 1857 at Tres Virgines in South California; and Lessen's peak (also in California) mildly renewed its activity only a few years ago. Mount Hood, in Oregon, gives off vapour, and two Washington peaks were slightly active about 100 years ago.

South America, on the other hand, has many volcanoes, both active and lifeless. The range of the Andes between Corcovada in the south and Tolima in the north is studded at irregular intervals with volcanic peaks. Some have only recently become extinct; but by far the greater number have been cold and dead for thousands of years. These include the loftiest volcanic

A magnificent air view of cloud-wreathed Popocatepetl—The Smoking Mountain, and its companion peak, Ixtaccihuatl—The White Woman Both are dormant volcanoes on the Mexican plateau



With a roaring waterfall in the background—on the icy slopes of Akutan, one of the many volcanoes in the Aleutian Islands off the coast of Alaska

mountains in the world, though perhaps the record for actual height should go to the island volcanoes of the Pacific. These have an unseen base, miles below the level of the sea. This depth beneath the water, added to their visible height, would make them easily out-top the Andes.

Extinct Chimborazo, in Ecuador, is 20,702 feet high, while Cotopaxi, at 19,550 feet, is the highest active volcano. Some of the ancient lava streams from the peaks of the Andes accumulated to great depths in the valleys below. So enormous were the quantities poured forth that lava a mile and a half deep has been measured in the ancient valley that is now the Cordillera de Vilca plain, in South Peru. This particular form of lava is to be found in the whole chain and has been given the name of "andesite."

Beauties of Popocatepetl

Central America has many active volcanoes and solfataras, the majority being near the west coast. They are a continuation of the great volcanic ring round the Pacific that begins in the Andes. Here on the Mexican plateau is the dormant volcano with the fascinating name of Popocatepetl, which means the smoking mountain. It is 17,500 feet high and dominates the town of Puebla, which glories in magnificent views of the towering peak. Rough roads used by the sulphur cutters wind their way towards the summit, but at 14,500 feet horses must be left behind, because the loose lava and ashes give them no foothold. The heat of the sun on the snow-covered cone is intense, although in September the thermometer averages only two degrees above freezing point, so high is the peak.

The reflection of the sun's rays on the snow blinds the eyes of ascending travellers, so that smoked glasses must be worn. The first Europeans to ascend Popocatepetl were an investigating party of Spanish soldiers sent by Cortes in 1510. The marvellous sight that met their eyes as they gazed down the crater is still as wonderful for those who make the journey to-day. Intensified by the light from the deep blue sky above, the

steep, rugged walls reach down in a glory of variegated colour.

Guatemala is also prolific in its volcanoes. One, Santa Maria (12,467 feet), which had remained dormant for centuries, suddenly erupted in 1902, and has been showing signs of activity ever since. The luxuriant forests that had overgrown its slopes were devastated by the new outburst. Another, Agua (meaning water), was so named by the Spaniards in 1541 after it had destroyed the former Guatemalan capital with a deluge of boiling water from its flooded crater.

Much farther north on the American continent is a virile centre of volcanic activity in the Alaskan coast range and the neighbouring Aleutian Islands. Mount Wrangell, on the Copper river, is still an active volcano. But the great part of the volcanoes in these mountain ranges seem quite extinct; the unexpected may happen, however, after centuries of quiet, as when the top of Mount Katmai blew off just before the Great War.

Unimak Island has two volcanoes which supply the natives with sulphur and the glassy rock called obsidian. Continuing along the northern arc of the Pacific ring, there are forty towering volcanoes in the Russian peninsula of Kamchatka, and here, too, are many hot springs whose waters flow together and actually form a deep river—the only really warm river in the world. Running south from Kamchatka is a string of islands that look on the map like stepping stones to Japan, and they carry the volcanic ring to Japan itself. They are the Kurile Islands.

In Japan itself fifty-four volcanoes are now recognized as recently extinct or still active. The most famous of them all is graceful, snow-capped Fujiyama or Fujisan. This great dormant volcano is venerated in Japan and pictures of it appear on thousands of vases, embroideries, gaily coloured screens and fans. But its beauty is marred now by the encroachments of Westernized Japan. The Temple Park, at its foot, is littered with cigarette packets and tin cans. But Fujiyama is not yet dead, and the faithful believe that she will yet pour the wrath of her vengeance on the sacrilegious.

Less picturesque but of far more immediate danger is Ko Bandai, 120 miles north of Tokio, which in 1888 blew off one side of its peak and blasted 3,000 tons of earth and debris over the nearby villages. But it is earthquakes rather than volcanoes which

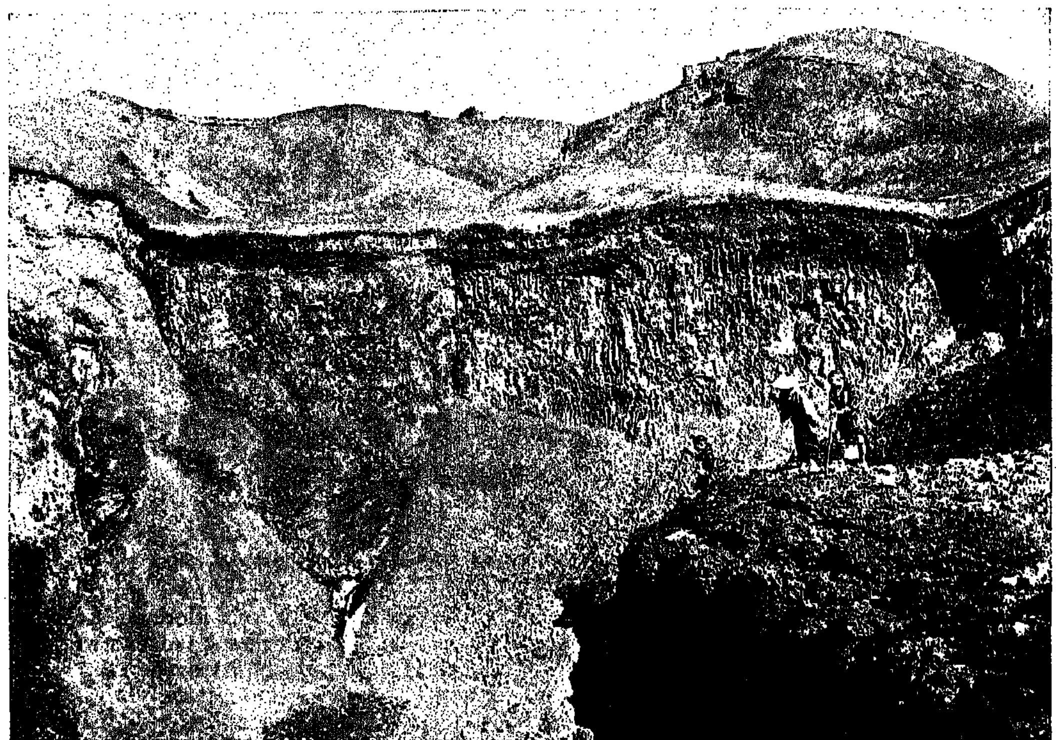


Photo: the late H. G. Ponting

In Japan—the land of volcanoes. The crater of Fujiyama, which is 500 ft. deep and almost 3 miles in circumference

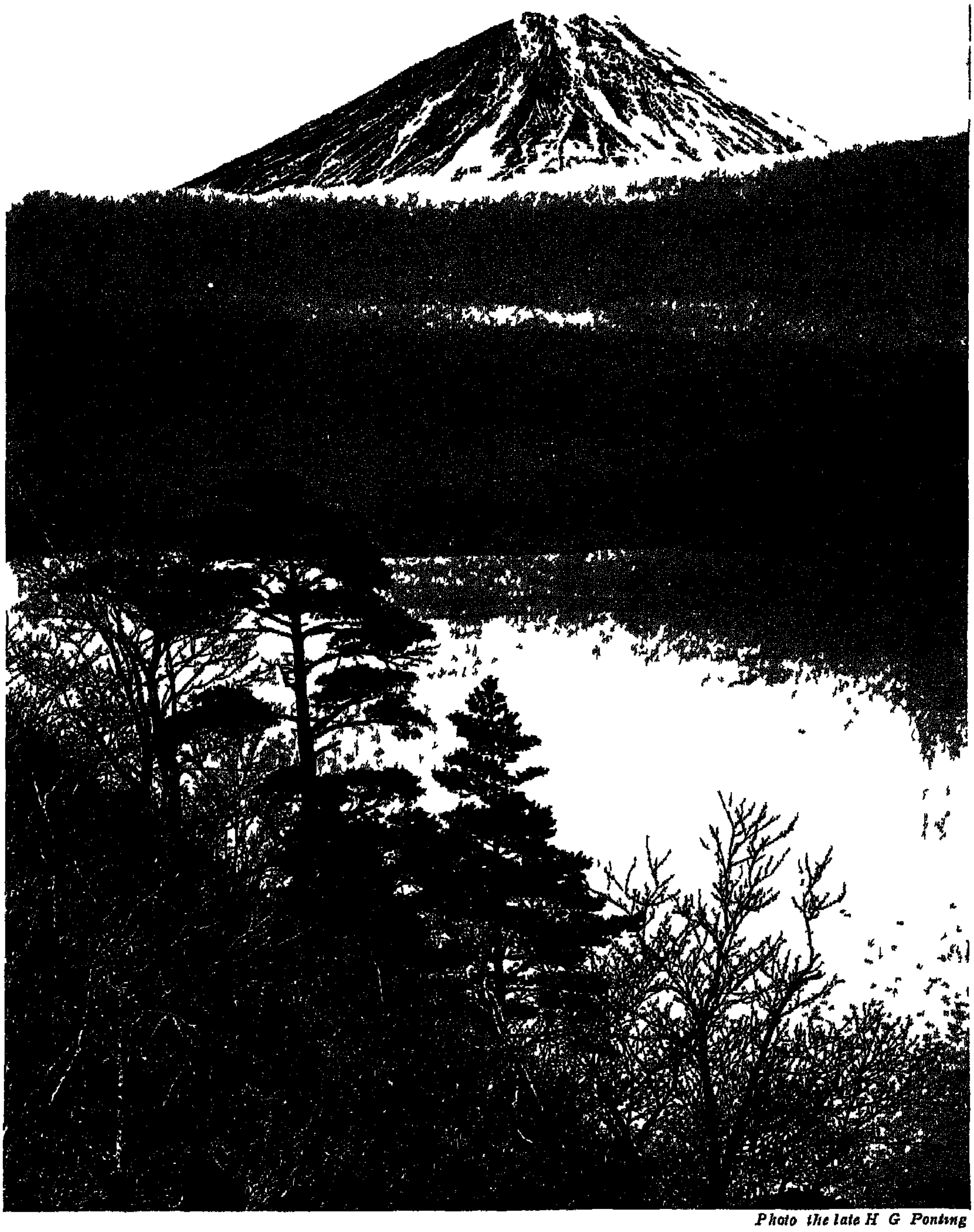


Photo the late H G Ponting

A truly beautiful sight—Fujiyama, the sacred mountain of Japan, with its snow-streaked peak towering above the clouds. In the foreground is Lake Motosu

devastate Japan so frequently, and these are dealt with in Chapter XXIX.

The clearly-defined line of volcanoes continues on through Formosa to the Philippines and then divides, for every island in the Moluccas and the Sunda Archipelago has its volcanoes and hot springs. It is here that the biggest volcanic eruption for centuries occurred in 1883, on the little uninhabited island of Krakatoa in the Straits of Sunda.

One Monday, in August of that year, people living thousands of miles away heard great rumblings and explosions. In Ceylon they were given, not even the most timorous heeded them. Even as long as three months before the final catastrophe, the drowsy peak awoke and began to pour out a gigantic column of smoke and vapour, estimated at seven miles high. Over both sides of the Sunda Straits fell a great rain of ash and pumice. An expedition that landed on the island a few days later had to wade ankle deep in fallen ash. A month later a second column of steam rose from the centre of the island.

Then a third column burst forth, belching up ash and dust with the vapour till a vast

Courtesy of K.N.I.L.M.

Krakatoa in full blast—a striking photograph taken from the air of enormous clouds of dense smoke pouring from this East Indian volcano

thought it was a warship practising gunfire. In Singapore vessels went out to look for a ship firing distress signals; and in Sumatra the troops were got ready, as it was believed that a fort was being attacked.

But no one suspected the beautiful little tree-laden isle of Krakatoa as being the offender. Volcanic eruptions, fiery lava streams and earthquakes were such commonplaces to the nearer inhabitants of Java and Sumatra that they would have suspected one of their own many volcanoes much sooner than the gently-puffing Perbuwatan peak on Krakatoa.

So, when warnings of impending doom canopy of cloud, many miles high, hung over the island. At night it was an awe-inspiring spectacle. Showers of white-hot lava hurtled into the heavens, turning a glowing red as they fell on the slopes of the peak. One moment inky blackness; the next, heralded by a startling explosion, a blaze of fire. Across the lowering dust-curtain leapt and flashed shafts of forked lightning.

With such quantities of fiery matter ejected from the small island it may be that sea-water had seeped into the boiling cauldron, cooling the surface lava and imprisoning the gases, for on August 26, 1883, with the loudest detonation ever heard, the north part

of the island was blown to fragments and the southern side of the opposite peak was cut clean off like a divided apple. Where once there had been hills 1,500 feet high was now a deep hollow over 1,000 feet below the surface of the Indian Ocean.

Tremendous air waves caused by the explosion encircled the entire world four times before their effect was too faint to be recorded. Three thousand miles away, at Rodriguez, the noise was heard distinctly. The fine volcanic dust was blown all over Africa, Europe, Asia and America. Day, for hundreds of miles, was turned into black night. For hours the crews of three vessels shovelled the constantly raining dust from their decks, and the captains strove in vain to find their way in the darkened Sunda Straits.

But by far the biggest terror was the tidal wave which followed. It rose to more than fifty feet in height, and swept wildly along the coasts of Java and the neighbouring islands, forced its way through the Indian Ocean to Ceylon, and was even mildly felt in the Thames estuary! Ships were destroyed like matchwood, harbours and villages around were completely wiped out, and 36,380 human lives were lost, mainly through drowning. More is said about this consequence of volcanic convulsion in Chapter V.

Meteorologists reported that sunsets all over the world were coloured for as long as three years after by the dust thrown into the atmosphere by the Krakatoa explosion.

Krakatoa lies at a weak point on the earth's crust, at the junction of two tremendous cracks or faults. Through these fissures on the sea bed has been forced the lava to build the hundreds of volcanic islands of the tropic seas. Java alone has as many as forty-nine great volcanoes.

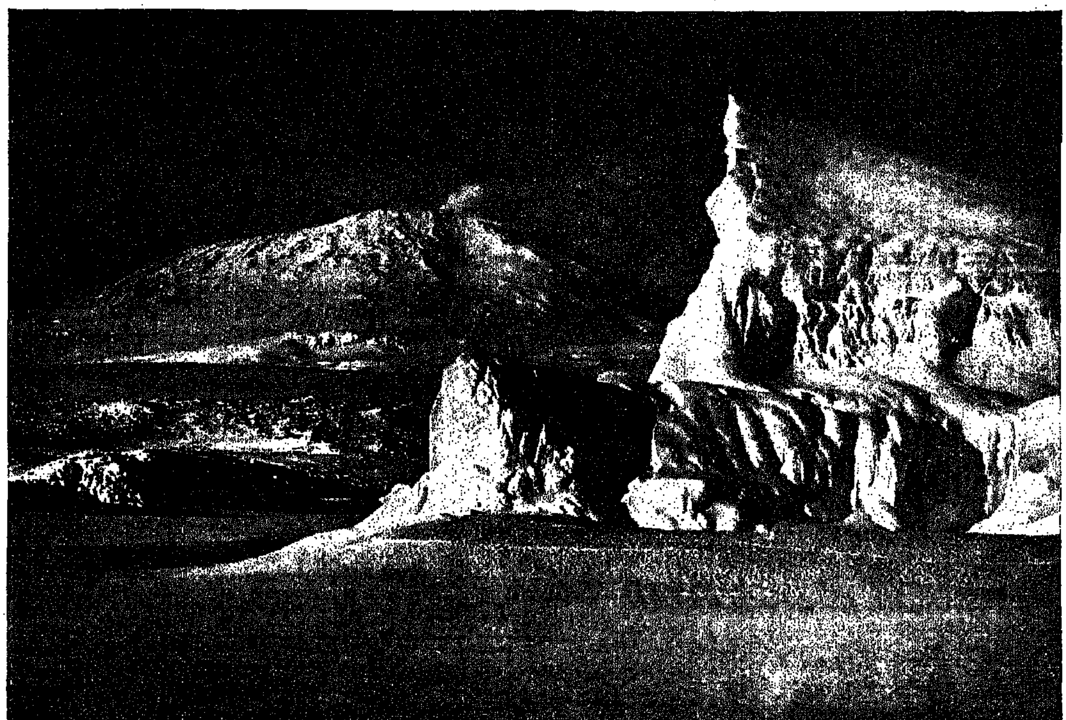


Photo: the late H. G. Ponting

An unique view of Mt. Erebus, the great Antarctic volcano, with a feathery plume of smoke issuing from its crater. On the right is the "Matterhorn Berg"

Extending almost as a southern limb to this great centre of activity are the volcanoes of New Guinea and New Zealand. North Island, in New Zealand, is a highly active volcanic region. In the centre of its pumice-covered plateau spreads the lovely lake of Taupo, some 238 square miles in area. Beyond this lake stretches a region, 5,000 miles square, of waterfalls, hot springs, and innumerable pools whose temperatures range from cold to boiling point. Many of the springs are noted for the remarkable cures

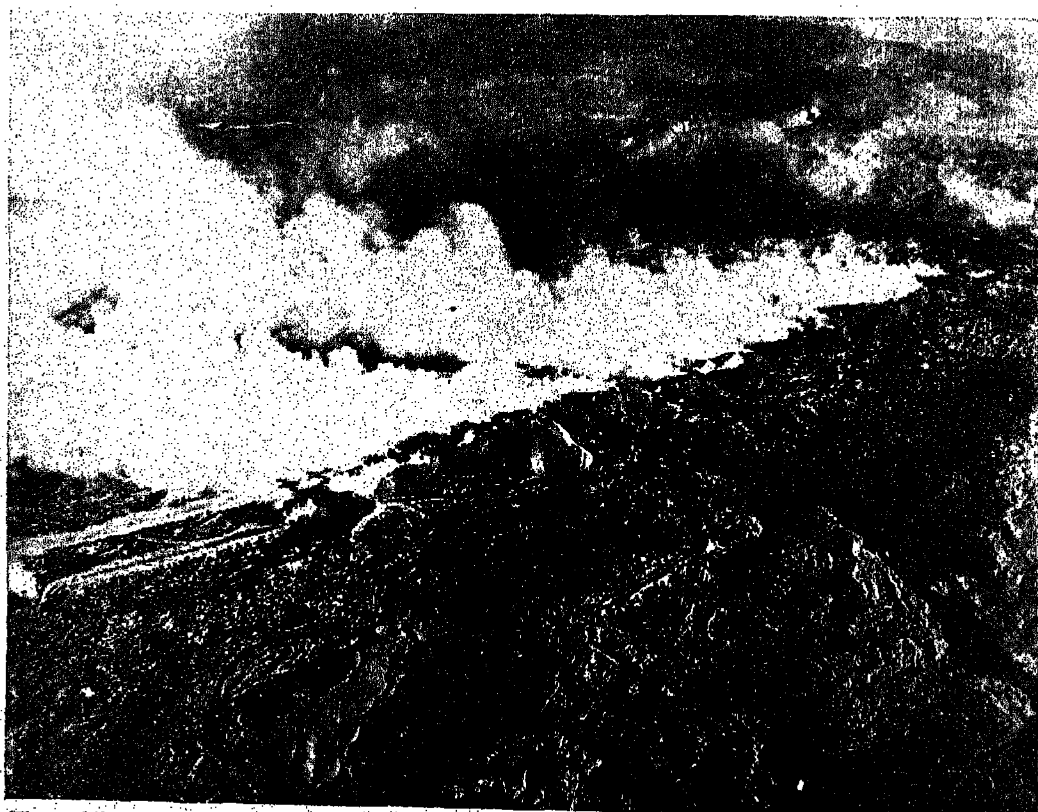
Courtesy of the "African World"

Looking down on the eternal snows in the crater of the extinct volcano Mt. Kibo, the higher of the twin peaks of Kilimanjaro

they have effected in sufferers from rheumatic complaints.

Far away to the south, in the Antarctic, we again meet with many volcanoes and volcanic islands—a queer contrast, mountains of fire in a land of perpetual ice and snow. Mount Erebus, the most majestic of all the volcanoes of Antarctica, is on the British territory of Ross Island in the Ross Sea, and is approximately 13,000 feet high.

It was on January 28, 1841, that Captain J. Clark Ross, in command of the discovery ship *Erebus*, sighted the great volcano after being the first explorer to penetrate the Ross



The world's largest volcano in furious action—an air view of Mauna Loa during the eruption of 1926, showing fountains of lava shooting into the air and then flowing down the mountainside

Barrier, an enormous floating sheet of ice, roughly as large as France. Mount Erebus is still an active volcano.

Right in the centre of the great Pacific basin lies yet another group of volcanic islands, the Hawaiian Archipelago. And as though a giant had stood on Hawaii and had cast a handful of pebbles to the south there lie, scattered all over the southern Pacific, thousands of islands mainly volcanic in origin, many even now quite active.

In the Hawaiian group there are fifteen large volcanoes, all extinct except three in Hawaii itself. One, Mauna Kea (white mountain), is the highest island peak in the world (13,825 feet). Mauna Loa (long mountain) is the twin of Mauna Kea and in bulk is certainly the world's largest volcano.

The most spectacular of the group is Kilauca. Its oval crater, which is the largest of active ones in the world, had walls 1,000 feet high a century ago. They have now become eroded to about half that height. Kilauea has a subsidiary crater within its main crater which acts as a check on the lava flow. When the boiling mass reaches a certain height it flows from the inner to the outer crater and largely disappears through some subterranean fissures. Kilauea has some grim tragedies to its account. In 1826 the lava flow, combined with an earthquake, killed thirty-one people, and the accompanying tidal wave swept away several small villages.

Kilimanjaro and Kenya Mountain

Crossing to Africa, there are several centres of volcanic activity, but in the main they are long dead and few of the craters show signs of life. They mostly appear along the great African Rift Valley (*see* CHAPTER XXXIX). When the land sank to what is now the Indian Ocean, a great cleft opened on the higher mainland left above sea-level. This formed the Rift Valley and along its weakest points volcanic activity was set up.

Two of Africa's highest peaks, Kilimanjaro and Mount Kenya, were then formed. Both are now extinct; indeed, one of the two summits of Kilimanjaro (19,325 feet) has a permanent ice-cap, giving birth to real glaciers.

Mount Kenya (17,040 feet) is now only the central core of an old volcano, from which glaciers spread down. Further along the great Rift lie a series of lakes terminating in the large Lake Rudolf. At this lake's southern end lies Mount Teleki, which unexpectedly burst into eruption at the close of last century.

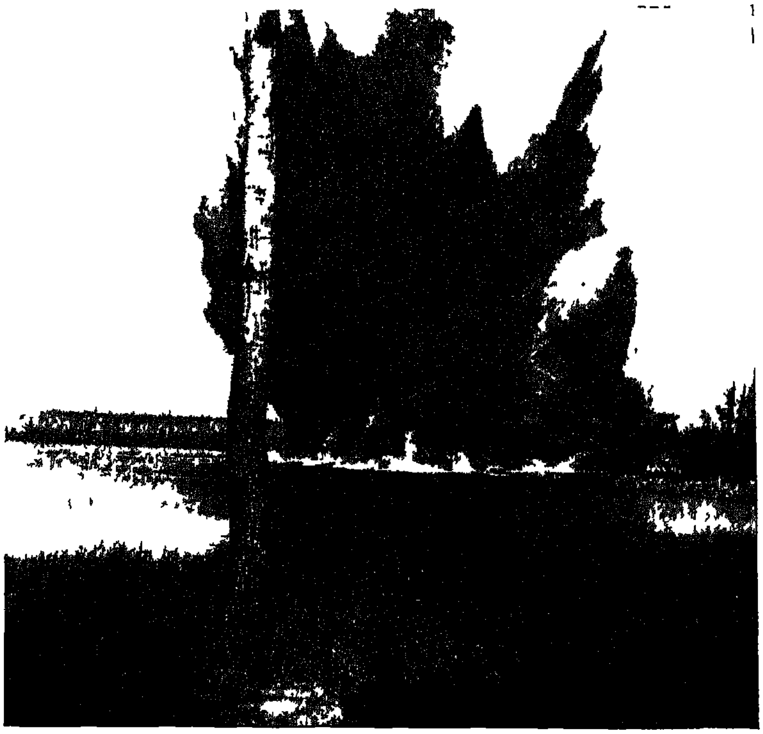
Photo British Movietone News

Kilauea in eruption

Top: **Masses of red-hot rock rolling down the mountain slopes.** ***Centre:*** **Palm trees borne down and burnt by the molten lava.** ***Bottom:*** **Dense steam and smoke arising as the lava reaches the sea**

CHAPTER XX
EXPLOSIONS TO ORDER

THE first and, for long, the only use of explosives was in propelling death-dealing missiles. Because of the impressive and terrible havoc which attends the explosion caused by war machines we are prone to lose sight of the great services that explosive agents render to us in altogether peaceable ways. It is true that man has used gunpowder, gun-cotton, dynamite and other explosives in order to kill his fellows, but he has utilized it also for the arts of peace —in such operations as the formation of railway cuttings and tunnels, the preparation of foundations for bridges, harbours, lighthouses and other structures, and the demolition of buildings.



Courtesy of Canadian National Railways

During the construction of a dam, temporary barriers—known as coffer-dams—have to be built to keep the water out while foundations are laid. These are afterwards destroyed, sometimes in the manner here shown where a coffer-dam, erected in connection with power scheme in Canada, is being blasted

More than one mediæval philosopher, impressed with the driving force of gunpowder, toyed with the idea of using it to force out the pistons of an engine; but the internal-combustion or "explosion" engine did not come until almost our own day.

Explosives are substances which, in certain conditions, develop a sudden and enormous pressure that is exerted on their surroundings. This pressure is caused by the rapid conversion of the explosive into a gas or gases having a very much greater volume than the original substance. An explosive may be either a solid, a liquid, or a gas, and examples of these three forms are: gunpowder, nitro-glycerin, and petrol-air vapour.

The first explosive invented was gunpowder and the inventor is said to have been Roger Bacon. His discovery was made about the middle of the 13th century, and gunpowder remained the only effective explosive until the middle of the 19th, when gun-cotton was invented followed by nitro-glycerin. It may seem a little curious that these two explosives are able to be prepared from such harmless substances as cotton-wool and glycerin. Yet, if cotton-wool is treated with nitric acid, plunged into cold water, washed until every trace of the acid is removed, and then carefully dried at a temperature not greater than that of boiling water, it becomes nitro-cellulose, or gun-cotton, widely used as a propellant in guns both large and small.

Glycerin is a clear sweet liquid often used in toilet preparations and medicines. By allowing it to drop into a cooled mixture of nitric acid and sulphuric acid, glycerin is converted into nitro-glycerin. In its liquid form this substance is so dangerous to handle that few countries will allow it to be sold or imported in that form. To render it portable, safe and manageable it has to be absorbed in some inert porous material, in which form it is known as dynamite. Since there is a number of different substances used for absorbing nitro-glycerin, it follows

that there are a number of different types of dynamite, each being known by a particular name. Some of the absorbents are quite harmless in themselves, but some are explosives or combustibles before absorbing nitro-glycerin. Blasting gelatine, for example, is a combination of nitro-glycerin and nitro-cotton, the latter being a less nitrated cellulose than gun-cotton.

Before passing on to the uses to which man has put these explosives it is necessary to say something about detonators and fuses. A high-explosive if it is to be effective must develop the whole of its energy instantaneously. For example, if a certain explosive were spread out in a layer over a large area and ignited with a match it would certainly flare away rapidly and there might be an explosion; but if on the contrary a quantity were packed tightly together and struck with a hammer, the whole of its enormous energy would be developed in a fraction of a second. Detonators are therefore always used for firing high explosives. They are composed of a highly explosive compound, such as fulminate of mercury and chlorate of potash, which is compressed into a small copper tube closed at one end. The other end of the tube is left open to receive the fuse to which it is firmly fixed.

Photo American Colony, Jerusalem

One of the many peaceful uses of explosives—detonating a great blast in the Athlit Quarries, Palestine, whence stone was taken for constructing the fine harbour at Haifa

Blasting away Thousand-ton Masses of Rock

Fuses, until comparatively recent times, consisted of nothing more than a trail of damp gunpowder, but this primitive and crude device has been almost entirely superseded by a made-up fuse of fine meal powder wrapped up in a non-inflammable and waterproof casing. To this a slow match—a cotton cord soaked in acetate of lead and afterwards rinsed out and dried—is applied; the flame passes from the fuse to the detonator and causes the high-explosive to develop its energy instantaneously. Nowadays the electric detonator is superseding the ordinary type, as it has obvious advantages and can be operated from a greater distance.

Anyone who passes along the north coast of Wales will observe that huge masses of rock have been cut away from the top of the mountains. Penmaenmawr, in particular, looks as though a huge knife had been drawn vertically down from its summit to some hundred feet or so below; then taken out, drawn across horizontally, and a huge slice removed. On the top of Penmaenmawr there is a slate quarry, and at regular times during the day explosions are heard denoting that a huge mass of rock is being split away from the mountain.

Methods of quarrying differ according to the nature of the quarry and of the kind of stone being worked, but the following will give a general idea of how the task is carried out.

Assuming that stone is to be quarried from the side of a hill, a horizontal hole about thirty feet deep is bored with an air drill. Into this bore-hole is inserted a dynamite cartridge which is pushed right to the bottom of the hole and then exploded. The explosion will hardly affect the bored hole but will blast away a small chamber right at the end of it. A still larger space will be required, so one or two more charges are inserted and the process repeated until the chamber is large enough for, say, 250 lb. of gelignite, an explosive which contains about sixty per cent. of nitro-glycerin. The gelignite is then pushed through the bore-hole with a wooden rod and packed into the end chamber. Two

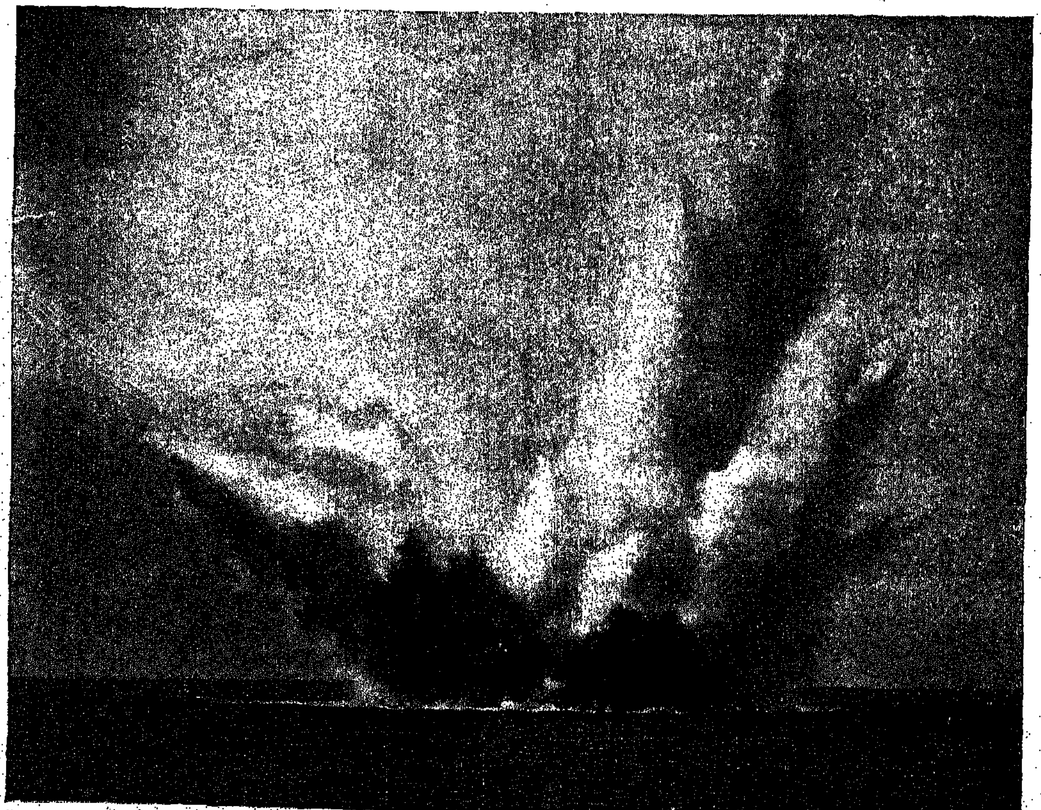
detonators, one as a standby in case the other misfires, are then inserted so that they touch the gelignite, and it is all firmly "tamped" or packed. The hole must be filled up with some material which will not allow the energy in the explosive to be dissipated uselessly. The more firmly the hole is tamped, the greater will be the effect of the explosion inside the chamber. Damp earth or clay is the usual tamping, though even water can be used. The charge is then fired and the rock splits from the inside.

The charge of 250 lb. of gelignite, mentioned earlier, if the hole were bored in the best position and the charge placed correctly, would displace about 2,000 tons of rock. It is usual in quarrying to split away large slabs or masses of rock and then, by drilling and inserting weaker charges, to split the slabs into smaller ones until they are ready for final sizing and shaping.

When blocks of rectangular section are required a simple yet ingenious method of blasting them to the approximate size has been devised. Along the horizontal face of the rock a series of vertical holes is bored and small chambers made at the bottom of these holes. A similar series of horizontal holes is bored into the vertical face of the rock and these filled with water. Then a small cartridge of gelignite is placed at the *top* of each vertical hole, the whole series being fired simultaneously. The explosion breaks away the rock along the lines of the holes, thus giving a number of blocks of approximately the same size and section.

Tilling the Earth with Dynamite

Mention has been made in other chapters of explosives used for breaking up wrecks and in working coal mines; but one of the most interesting of the industrial uses to which dynamite has been put is in the service of agriculture. For hundreds of years farmers have ploughed their lands, season by season, breaking up the top layer of earth and turning it over. In this surface layer the seed is sown and year by year the crops absorb the nourishment in this shallow top stratum. By manuring, by the use of chemical fertilizers, by ploughing in feeding crops and by rotating his crops, the farmer



Removing a menace to shipping. Water and wreckage shooting 100 feet into the air—the effect of 250 lb. of gelignite used during the blowing up of a steamer sunk in 54 feet of water off the Kentish coast

Courtesy of the Canadian Government

Huge masses of tree-trunks floating down from timber forest to sawmill often become hopelessly jammed and have to be released by explosives. Above, lumber-jacks are blowing up a big log-jam on the Montreal River in Northern Quebec

is able to restore some of the goodness to the soil, and sometimes he lets the land lie fallow to achieve the same purpose; but it never regains the richness of virgin soil. Meanwhile underneath this layer of earth there is other soil which has never been tapped and which has become more and more compressed. The roots of the crops cannot find their way into this virgin soil because it is too hard, and the rain cannot percolate through it. Because the moisture cannot find an exit from the top layer of earth, this layer is often sodden in winter; on the other hand, when the local moisture becomes evaporated, the stratum becomes too dry in summer

In order to remedy the state of affairs described, the tiller of the soil resorts occasionally to deep digging, and various mechanical cultivators are used for the purpose. In America, and some other parts of the world, farmers have found that dynamite digs the ground to much better effect than the mechanical cultivator. Holes are driven into the ground about twelve feet apart to a depth of four feet, so that they penetrate three feet into the hard crust. At the bottom of each hole a cartridge of dynamite is placed with a detonator and fuse, and the charge fired; the result is that the deeper soil cracks and breaks up in all directions, and becomes as loose as top soil that has been ploughed. In addition, the dynamite kills the grubs that abound in the soil, aerates the ground, and liberates the chemical foods necessary to the health of the crops. The rain drains away to the lower layers of earth which are still unbroken and forms a natural reservoir; and, most important of all, the roots of plants are enabled to grow downwards in their search for nourishment, instead of having to travel horizontally along the surface of the subsoil layer.

The general method of firing the charges is for three or four workers, each starting at the top of a row, to proceed along the rows, keeping practically level and lighting the fuses as they pass.

Orchards, too, have benefited by the use of dynamite, both in the initial stages of

planting and when the trees are fully grown. In planting the sapling a hole is blasted out with dynamite; the loosening of the surrounding earth gives the trees better opportunities for healthy growth. As regards fully grown trees, these can be aided by boring holes three or four feet deep at a distance of four to six feet away from the trees. Charges exploded in these holes break up the earth round the roots and the treatment confers on the tree the advantages mentioned above.

It is hardly necessary to mention the great value of dynamite to the settlers in Australia, America and other new lands. The clearing of land for agricultural purposes would have been almost impossible without the use of dynamite to blow out the enormous tree stumps after the trees had been felled. Explosives are extensively used in drainage work: ditches can be made quickly and cheaply by employing dynamite; and swampy or marshy ground can be rendered eventually suitable for ordinary crops if holes are bored deep enough to penetrate the clay pan that is holding up the water above, and charges of dynamite are then fired within the impervious layer.

All over the world dynamite and the more powerful explosives are being used to Man's good. Massive rocks impeding a flow of water, whose power could be harnessed by means of water turbines, are blasted away; floating down from the log camps of Canada to the sawmills, huge trees that have become jammed are released by a charge of dynamite. Steel girders and brick walls, once the framework of stately buildings whose usefulness is past, are demolished with speed and safety; an immense towering factory chimney can be razed and made to fall in narrow limits by the skilful use of explosives. In very many ways dynamite is proving a powerful aid to Man in making use of the resources of the earth, but Man is also using it for his own destruction.

Great Guns for Man's own Destruction

The first discovered explosive, as we have said, was gunpowder, and it is recorded as being used in cannon about the middle of the 14th century. The gunpowder was pushed in at the muzzle, rammed home and a pad of soft material was placed against it to prevent it from moving. A solid ball of iron, wrapped in a greasy cloth, was then pushed down the muzzle until it made contact with the soft pad; and into the touch-hole at the breach was poured a small quantity of powder for the "priming" charge. A light was applied to the touch-hole to ignite the propelling charge in the barrel of the ordnance and with a sudden explosion, a roar and a flash of flame the cannon-ball hurtled out of the muzzle at the enemy.

This type of war machine, however crude it may seem to-day, spelt the doom of castles and forts of the Middle Ages and played its part in the Napoleonic Wars of the 19th century. Rifled guns did not begin to supersede smooth-bores until half the century had run, and breech-loaders were made after 1858. Rifled muzzle-loaders long continued to be made, up to ordnance of sixteen-inch calibre and weighing a hundred tons. In the present century progress has been both great and rapid in field guns, siege guns and naval ordnance. New methods of gun-making were evolved, more efficient projectiles, and more powerful propellents. Not until the Great War, 1914–18, did the new types of gun and the new types of explosive play any great part in warfare, so that we must regard them entirely as modern inventions.

The Forts of Liège and Namur

The first of the giant guns that made this war different from earlier conflicts was an Austrian invention called the Skoda mortar, and its use in the early days of the Great War was responsible for the Belgians being unable to hold the forts of Liège and Namur, and for their being driven out of Antwerp. When attacking Antwerp three motor-cars, each of 100 horse-power, were used to transport respectively the gun, its platform and its mount. First the foundations were dug out, then the platform laid in it; next the mount was bolted on the platform, and the gun then fixed in position. The nearest point to Antwerp to which the enemy gun could be brought was distant seven and a half miles, and since, of course, the gunners could not see the object they wished to hit—in this case a large building—careful calculations were made for indirect fire. The gun was loaded with an enormous shell weighing 800 pounds, and trained into position; its muzzle, of course, pointed upwards. So powerful and effective were these giant guns that Antwerp was soon made untenable and had to be evacuated.

Later in the War still bigger guns were built, the Germans using some to throw shells on French towns, including Paris, from distances of more than twenty miles.

Few people know the extreme effective range of the most modern guns, since their capabilities are kept secret; it is doubtful, however, if range is so important as the measure of destruction which a single shell can bring about. Moreover, aircraft are coming to usurp the function of long-range ordnance, at least as far as land warfare is concerned. ·

All these huge weapons of war have been made possible by the discovery of new, powerful and manageable explosives. A gun loaded with a missile which in itself is a container of explosive materials and which is projected through space by means of another explosive becomes a weapon capable of destroying not only Man himself but all his works. When the shell itself is made to fire another shell at the appropriate moment, and so add yet further to its already great range, we obtain an engine of death terrifying in its potentialities though of fascinating interest.

The shells used in modern guns have been evolved from bombs. In the earlier stages of their development they were like cannon-balls in shape but instead of being solid they were made hollow and filled with gunpowder. A slow-burning fuse stuck out at the top and this had to be lit before the bomb was placed in the barrel of the gun. The propelling charge in the gun had then to be ignited, and if the luckless gunner were not quick enough, the bomb might explode inside the gun with disastrous results. This type of projectile by gradual stages evolved into our modern *cylindrical shell.*

There are different types of shell and they are used for varied purposes, the better to effect destruction of personnel or material. The shrapnel shell is like a gun within a gun and contains within its casing a bursting charge and a mass of bullets. Its fuse is timed to ignite the bursting charge when the shell is above the target, so that the bullets it contains are hurled in all directions.

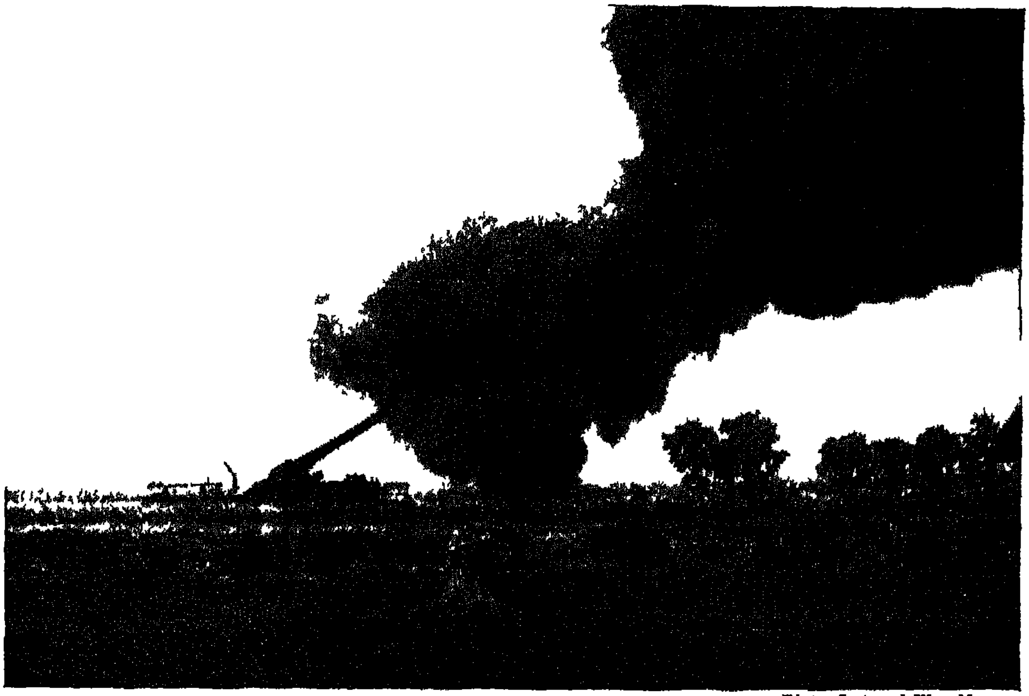
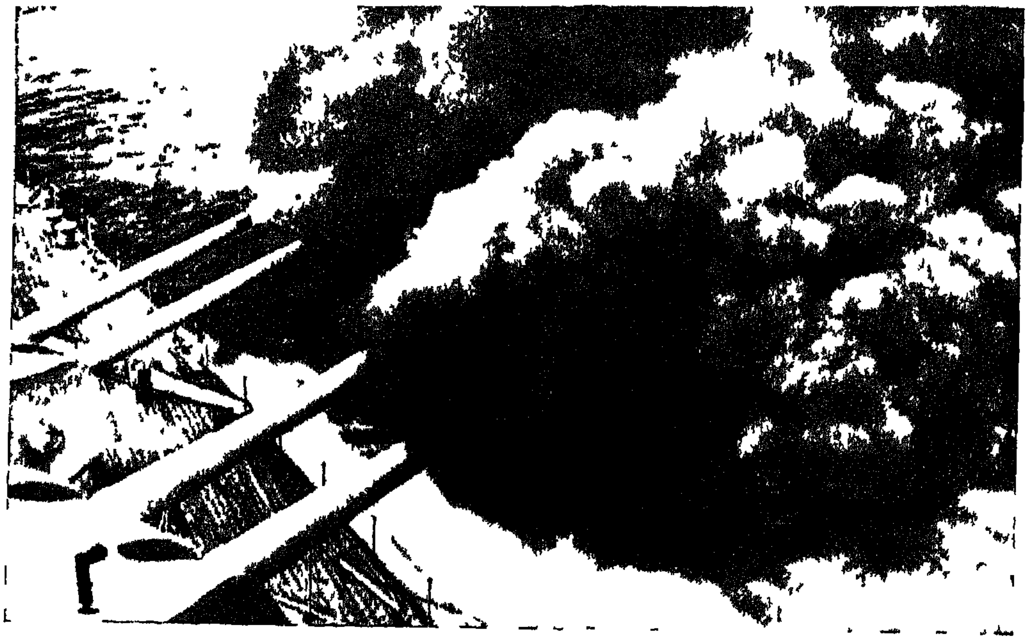
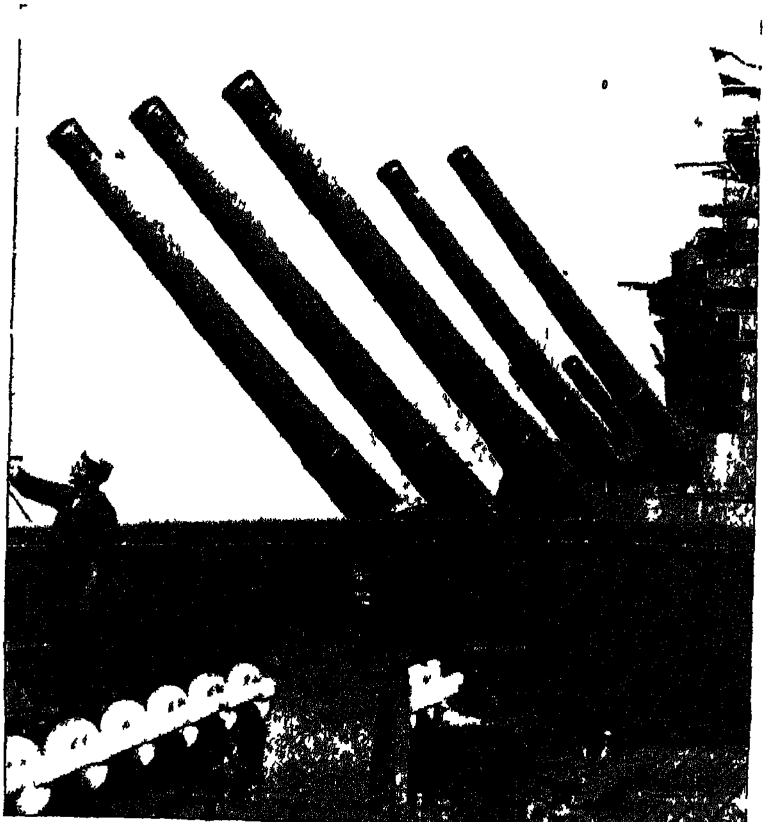


Photo: Imperial War Museum

Typical of the monstrous death-dealing machines which no one ever wants to hear again—a 12-inch gun on railway mounting in action on the Western Front during the World War, 1914-18. Guns far larger than this dropped shells in Paris from a distance of 75 miles

Common shell, the progenitor of high-explosive shell, is designed to demolish the material impediments to the attacker's advance. High-explosive shells, when they burst, destroy everything around them within a wide area. The enormous air pressure set up in the vicinity is enough to destroy human life and rend the bodies of the victims. In the early days of the Great War, high-explosive shells were loaded





The "teeth" of the Royal Navy idle and at work. 16-inch guns on *H.M.S. Rodney*, showing the high angle at which they can be trained, and (*top*) the 8-inch guns of *H.M.S. Sussex* belching forth destruction

with picric acid, known as lyddite, but shortage of the chemicals from which it is made forced the warring countries to find other material. Trinitrotoluene (T.N.T.), obtained from coal-tar, was employed to a certain extent, but here again there was difficulty in obtaining the materials for its manufacture, therefore ammonal, a mixture of ammonia nitrate, aluminium and trinitrotoluene, was employed. This in turn was superseded by amatol, a mixture of ammonium nitrate and trinitrotoluene in the proportion of 40 and 60 or 80 and 20. Though amatol is a more powerful explosive than either picric acid or trinitrotoluene, alone it is less violent. From the view-point of the artillerist this characteristic is an advantage, because

the explosive does not shatter the shell into such small pieces. When a shell is blown into minute particles it is less capable of killing individuals, although, of course, if any shell makes a direct hit, man or material is utterly destroyed.

The shells used in naval warfare are charged mainly with T.N.T., for lyddite has proved itself less capable of piercing the armour of warships. During the battle of Jutland, British shells loaded with lyddite failed to break through the armour of the German warships, while German shells loaded with T.N.T. completely destroyed the battle cruisers *Queen Mary*, *Indefatigable* and *Invincible*, and the cruisers *Black Prince* and *Defence*.

On land again, the power of explosives is demonstrated in another way besides being projected from guns. Sappers and miners burrow their way under enemy positions and lay mines which, when they are exploded, fling tons of earth hundreds of feet into the air and destroy vast areas of land. At Messines, during the Great War, a charge of 90,000 lb of explosive was used in a single mine, and the total weight used in that sector was over a million pounds.

Guns are not, however, the only means of projecting explosives at an enemy. At close quarters bombs, called grenades, are thrown by hand, and during the war of 1914–18 were even projected by catapult. Hand grenades are miniature shells loaded with lyddite, and are employed to attack men in dug-outs, buildings, or other quarters where a direct attack is not feasible. Though no bigger than a cricket-ball, a grenade can nevertheless deal death to half a dozen men.

In the wars of the future a decisive factor may be the aerial bomb—perhaps the most terrible weapon of all—dropped from the sky by bombing aeroplanes that have a cruising speed of nearly 250 miles an hour and are capable of carrying two tons of bombs. Against them defensive measures are being concerted, but it is doubtful whether any anti-aircraft gun can prevent them carrying out their work of destruction. Experts say that those huge floating castles, the

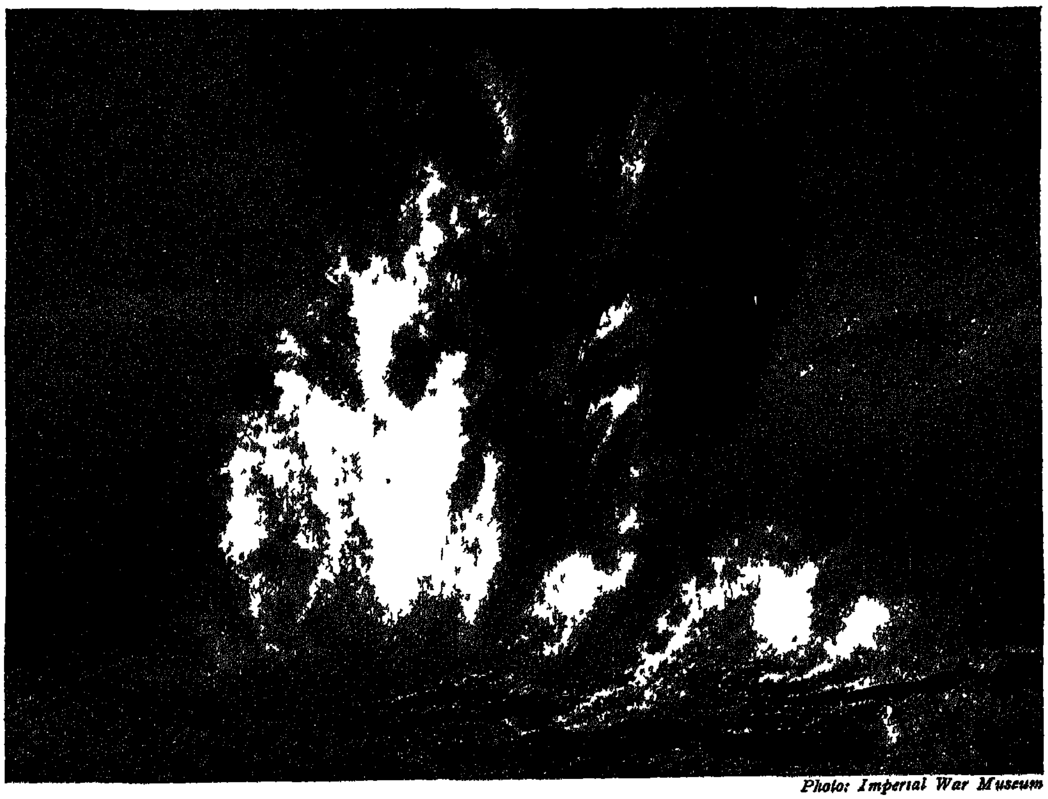


Photo: Imperial War Museum

A dramatic and awe-inspiring spectacle—the explosion of a depth-charge. This heavy charge of high explosive is detonated some distance below the surface of the water and is intended for the destruction of submarines. It is usually dropped from destroyers or similar craft

warships, heavily armoured though they are, may be badly damaged without a bomb even touching them, for so powerful are the latest aerial missiles that if they drop close to the ship and explode under water, the armour may be fractured and the rivets strained so much that the vessel will take in water; even propellers and rudders, it is said, will be put out of action. If a warship suffers a direct hit from one of these bombs it becomes a twisted mass of wreckage.

It is only fair to say that other experts rebut these premises and maintain that the battleship will still be able to hold its own against aerial attack. A counter-measure is the use of a special type of warship—virtually a floating anti-aircraft battery—that will protect the battleships from aerial attack and must in turn be protected from hostile sea-craft.

Another type of bomb is the torpedo. Introduced for use by special torpedo vessels and submarines, it has its counterpart in a similar machine developed for projection from aircraft. The naval torpedo is in itself a miniature submarine vessel fitted with its own engines and screw-propellers and bearing a head filled with high explosive. When launched it travels at 40 knots or more, the head exploding when its nose strikes the side of a vessel and blowing a hole in it. The aerial torpedo attains great speed, hurtling down on vessels or on towns and creating havoc wherever it strikes. The latest experiments are directed towards evolving a torpedo which, when dropped into the sea, will swim round in circles. It is hoped that in following this circuitous route it will make contact with and blow up vessels that a direct attack might miss.

CHAPTER XXI

DRY PLACES OF THE WORLD

SCATTERED about the world lie vast tracts of land which are of little or no use to man. Owing to excessive dryness of climate they cannot support a sufficient vegetation to render them attractive human habitations. Transport problems present insuperable difficulties. The scanty plant and animal life existing upon them do not offer the means upon which thriving communities can subsist. The great races of mankind have turned from such forbidding areas to the more temperate zones. Only the wandering tribes have remained to eke out a precarious existence in the great deserts of the world.

These deserts—areas "deserted" by man—are mainly found in tropical and subtropical regions where the annual rainfall is less than ten inches. Certain of these are so arid that sometimes years pass without their experiencing any rain. Aden, the British port on the south-western edge of the great Arabian desert, offers a typical example of such a condition.

The popular idea of a desert is that of a vast tract of sand situated in close proximity to the equator. This is not altogether correct, for in Central Asia there are great barren stretches in quite temperate regions. But the dryness of the air and the position of such deserts, in the heart of a great continent away from the cooling moisture-laden winds of coastal areas, produce high summer temperatures.

The scantiness of the rainfall is mainly owing to the fact that high mountain barriers rob passing clouds of their moisture, and so prevent the prevailing winds from moistening the arid land on the other side. Arabia, for instance, would have a definitely higher rainfall if, as the south-west winds swept over, their moisture had not already fallen on the Abyssinian highlands. The Shingle desert of Patagonia is swept by westerly winds which have already deposited most of their rain on the western side of the Andes.

Occasionally an area becomes a desert owing to some freakish local cause, as is the case with the Indian or Thar desert, which, lying between the Indus and the source of the Ganges, is situated in a region seemingly inaccessible to either of the main branches of the wet south-west monsoon.

In the great stretch of desert in tropical and subtropical North Africa, the insufficient rainfall is owing to an entirely different cause. The Sahara, Libyan, Nubian, Egyptian, and Arabian deserts all lie along a great belt north of, and parallel to, the equator. Colder winds, blowing from the northern temperate regions, expand as they rise high above the hot, desert lands, and do not drop their rain, but carry it southwards to water the equatorial forests and swamps.

The Sahara is the world's largest desert. It is, in reality, a gigantic plateau about 1,200 feet high and three-and-a-half million square miles in extent, or roughly the size of Europe without Scandinavia. Scattered about its vastness are the remains of old mountain ridges worn away by the action of wind and sand. To the north it is bounded by the Atlas Mountains, which are quite distinct from the desert, for geologically they belong to Europe. On its southern extremity the Sahara merges into Nigeria, and on the west is bounded by the coastal plains fringing the Atlantic Ocean. Its eastern border, the Libyan desert, is only a political demarcation, since France controls most of the Sahara and Italy the Libyan desert.

Scientists have put forward several theories to explain the presence of the tremendous quantities of sand in the Sahara. The explanation which is now generally accepted is that the sand is the outcome of geological changes brought about by the ending of the Ice Age. The great ice barrier extended as far as Central Europe, and the Sahara was in a temperate zone and consisted of vast plains of grassland when early man first inhabited it. As the ice barrier retreated northwards the winds became drier and drier, plants shrivelled, and throughout countless centuries the parched soil was carried away by whirling winds in the form of dust storms. The heavier part of the soil—the rock grains—remained, since the wind could not carry them far. It is of these rock grains that the sand of the present Sahara desert is composed.

In the Sahara the summer heat is very great, especially in the west. The hottest night temperature known is 104 degrees Fahrenheit, but the average summer night temperature is 77 degrees. In the daytime, recordings have been made as high as 132·8 degrees; this may be compared with an English heat wave of 90 degrees! As in most deserts, there is a sharp distinction between day and night temperatures. On one or two winter nights each year the ground in the west may even freeze, whilst in the central areas frost is more common.

Photo· American Colony, Jerusalem

Clouds of blinding sand that are liable to appear with lightning suddenness in the arid waste-lands—typical desert whirl-winds seen between Kirkuk and Bagdad, in Iraq

Fogs are frequent along the coast where the Sahara meets the Atlantic, caused by the meeting of cold currents of sea air with the hot air from the desert. Winds are generally light and irregular, but dust storms, whirling sand pillars, and other violent air disturbances are liable to occur with scarcely a moment's warning.

Only plants and animals that can exist with a very limited amount of water are able to live in such burning desert regions. The date-palm and tamarisk are the only trees

Photo Fanter-Akademia

The "Ghibli"—the desert wind of the Northern Sahara—continues its work by day and night. A deserted town being slowly covered by sand, near Murzuk

to be seen, and they grow in the few areas where water is found. These tracts, where coarse grass, date-palms and little desert plants fringe a small pool or spring, are known as oases. The desert plants often have the most ingenious methods of obtaining water. Some have leaves thickly covered with sensitive hairs which nightly absorb every drop of dew the moment it comes in contact with the plant. The most remarkable, however, is the Rose of Jericho (Anastatica): as soon as the dry season commences, the plant contracts its stiff, fern-like leaves, curling them over like a ball of dried bracken. The wind tosses the ball for miles across the sandy wastes, sometimes for years, but the plant will never open until it alights on water or on damp ground. There it opens, puts forth small white flowers, and seeds in a very short time. The dried plants can be bought in this country and grown indoors.

The largest animals usually found in the desert are certain species of deer and antelope. The lions that used to prey upon them are rapidly vanishing from the Sahara. Jackals, foxes, badgers, and rats occur, and innumerable lizards, scorpions, locusts and flies. Birds such as duck and heron are occasionally found near the smaller oases, and ostriches roam on the higher land in the south-west. Hyenas haunt the desert borders, but never penetrate far into the waterless wastes.

Since the days when Rome and Carthage were the world's great powers, explorers have ventured into the dreaded Sahara in the hope of discovering its secrets. Regular trade routes sprang up, connecting the oases. The few hardy, wandering tribes became merchants in salt, ivory and dates, carrying their goods on camels. Timbuctoo has been an important township for centuries, and is still the centre of the Sahara salt trade, the salt being collected from the dried lake beds of the Juf district.

Now, the motor-car and aeroplane are ousting the camel caravans. The French recently erected a line of beacons right across the Sahara. They are to guide the night-flying planes of the Trans-Sahara Air Service. The pylons which support the beacons are made of steel, and are built very high to avoid being buried by deep sand drifts. The beacons light automatically when dusk comes, and hold enough fuel to last two years.

Photo Fanter-Akademia

The fast-riding camel is a possession beyond price to the desert tribesman. Here is a Tebbu of the Northern Sahara with his *meharis*, riding camels famous for their speed. The saddle, or *ragla*, rests in front of the hump and the animal is guided by the rider's feet on its neck

The adjoining Libyan desert extends from the Mediterranean to the Sudan. Across its dreary dunes and sandy wastes there is only one known route running north and south, through the oases of Kufara. Travellers have described the dunes of the Libyan desert as "great motionless waves 200 feet high with an endless trough sometimes stretching for fifty miles."

During Roman times that part of Libya bordering the Mediterranean was a flourishing colony with important cities. The constant encroachment of the desert sand has buried many of these. The best preserved structures are probably those of Lebda. The treasures of this once-magnificent and rich city have been wonderfully preserved by the sand which now covers them. Although the great weight of the sand broke down whole walls, many beautifully worked columns and cornices have been found intact.

Until 1911, Libya was a Turkish possession. In that year an Italian force crossed the Mediterranean and seized the capital, Tripoli. Since Libya has become an Italian colony many good roads have been built, and irrigation schemes are still in progress for the growing of cotton for Italian textile factories.

A large area of the Libyan desert has been set aside as a sanctuary for animals and birds—something like a tremendous Whipsnade. There, the ibex, addax, onyx, and other kinds of deer are becoming quite tame. Even the wild ostrich, which for thousands of years has inhabited these regions, has by kind treatment lost much of its fear of man. In cairns on slightly higher ground, human remains thought to be seven thousand years old have been discovered, together with ancient strings of turquoise beads, and waistbands ornamented with ostrich shell.

The Libyan desert would continue straight across to the Red Sea but for the well-irrigated strip of land bordering the Nile. The Red Sea is a part of the Great Rift Valley, a rock fault which stretches through East Africa to Palestine; and the connecting deserts of Arabia, Persia, and the salty Iran plateau are geologically a part of one great arid belt.

In the Arabian Peninsula, a tract of country six times the size of Germany, there are only 7,000,000 inhabitants. [illegible] one of the hottest places on earth and offers few attractions for human habitation. Not a single river traverses its arid expanses, and were it not for the underground water that crops out here and there from the limestone subsoil, the interior would be quite uninhabitable. Two of the bigger oases contain famous cities, Mecca and Medina, the

former the birthplace, the latter the burial place of the prophet Mahomet. A railway already connects Bagdad with Medina and is being continued to Mecca. Its main source of traffic is the conveyance of the countless thousands of Moslem pilgrims, many of whom come from distant parts of Asia to visit the Holy Places.

Date palms flourish in all the oases and

Eastward and somewhat north of this Sahara-Arabian desert belt lies a great barren region north of the Himalayas. Here are the little-explored Takla-Makan and Gobi deserts.

The Takla-Makan is the least inhabitable of all deserts, in spite of the fact that it forms the basin of a large river, the Tarim. Yet here, hundreds of years before Christ was born, flourished important towns, the seat of that Mongolian culture which the Chinese claim as the source of their own civilization. Rising in the lofty Pamirs, two streams—the Yarkand and Kashgar—flow rapidly north-eastwards through rocky, desolate country until they slow down in the north of the desert plateau of Takla-Makan. There the two meet and from that point on their waters are known as the Tarim River. From the
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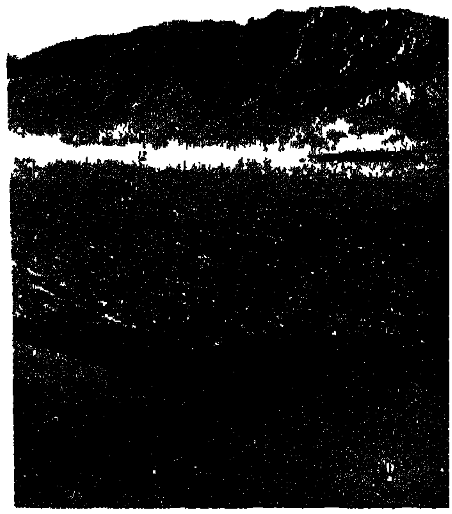

'art of the vast Gobi desert of Chinese Central Asia.

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exceptionally uniform and free from dust is able to make the strange singing tones as it slides down the dune slopes.

Marco Polo, the famous Venetian traveller, journeyed in the latter half of the 13th century across the Takla-Makan, then known by its ancient Chinese name, the Desert of Lop. The camel caravan took thirty days to cross the desert and Marco Polo's 600-year-old

descriptions read as true of conditions in the Takla-Makan to-day as then. "The journey is invariably over sandy plains or barren mountains, but at the end of each day's march you stop at a place where water is procurable. . . . At three or four of these halting places the water is salt and bitter, but at others it is sweet and good. In this tract neither birds nor beasts are met with."

He relates, too, the desert superstitions of demons calling unwary travellers from the caravan routes. "Almost passing belief are the stories related of those spirits of the desert

explorer Przhevalsky to tell the world in 1877 that the Tarim emptied its waters into Kara Koshun, a lake in the south.

Geographers and explorers argued over the matter until, in 1901, the whole district was carefully explored by Dr. Sven Hedin, the Swedish traveller. He found that the mysterious Lop Nor was in truth a wandering lake. The Tarim had changed its course for 1,600 years to flow south; and more marvellous still, he later found that the vagabond lake was again, in 1928, returning to its ancient bed in the north.

Photo: Sven Hedin

wn to the Chinese as Sha-mo, this huge barren waste is supposed at one time to have been covered by a great ocean

which are said at times to fill the air with the sounds of all kinds of musical instruments, drums and clash of arms." Marco Polo had obviously come across the singing sands.

It is in the eastern portion of the desert that the mysterious Lake of Lop Nor lies. The Chinese believed that the Tarim was the source of their great Hwang-Ho or Yellow River, and that in its course it was swallowed by the Lop Nor to re-appear again after a subterranean course in the Hsing-su-lai, the Sea of Stars, a lake in north-east Tibet where the Hwang-Ho has its actual source.

European maps of 200 years ago marked the lake as being in the north-east of the Takla-Makan, for that was where the old Chinese map-makers of a thousand years before had placed it. But no European had ever seen the lake. Even Marco Polo had travelled south of it and never mentioned it in his book. It was left to the Russian

Sven Hedin suggests that once again the famous silk route from China to Rome may open. Once more the ancient town of Lou Lan on the lake's border may bustle with life and trade. Already the returning waters are making a strip of desert green with vegetation. Tamarisks are springing up and young poplars are rising above the level of the grass.

Sven Hedin considers it more than probable that Lop Nor is the remnant of a tremendous lake which filled the desert basin in the Ice Age. Such a lake would have been comparable with the Mediterranean Sea and must have been fed by glacial streams from the great mountains lying to north, west and south. When the ice retreated, the rivers could not compete with the evaporation and the winds; so their waters dwindled and over a vast area the soil was blown away, leaving only the heavier sand grains behind.

North-east of the Takla-Makan lies the

much larger Gobi desert, called by the Chinese Sha-mo, the sand desert, or Han Hai, the dry sea. It is a plateau, 3,000 feet above sea level. Great undulating stretches of coarse grass occur here and there in the boundless waste of yellow sand. Scattered about the Gobi are many salt swamps, remains of ancient lakes.

Although several fertile oases relieve the general aridity of the Gobi, the hard snow-bound winters make them very different from the well-developed oases of the warmer Sahara. It was from nomad tribes who trekked between these watering places that came the fierce warriors who terrorized the early civilized world. Genghis Khan and his hardy Mongol hordes came from the Gobi. The great Kublai Khan, conqueror of China, was originally ruler of the wild mountain country bordering this great desert.

During Sven Hedin's journey across the Gobi he found many remains of earlier cultures. At one camp the expedition collected coins of an early Chinese dynasty, seventy copper and one hundred and seventy iron objects, and arrow heads. Near by were curved stone knives and stone axes, relics of a yet older group of people, of the Stone Age.

Existence for the traveller is made miserable when a sand-storm sweeps the Gobi. The fine dust penetrates through tent cloth and soon every article is coated with a yellow layer. Even the water is thick and yellow like soup. Camels are the chief means of transport here as in the Sahara. Many are only half-tame, having been captured from the herds of wild two-humped camels that roam the Gobi. So necessary is this animal to the scattered Mongol population that even murder is considered a lesser crime than the theft of a camel.

Antelopes and gazelles, hares and partridges also eke out an existence in the desert where scanty pasturage affords them subsistence and brackish water is occasionally found in small hollows. Small oases are being threatened by the hungry camels, however, for as soon as new young trees make their appearance above ground, they are eaten off. Only very old trees are to be seen in many of such halting places.

While most of the inhabitants live in yourts—skin tents over a wooden frame—many monasteries have been built near springs or water-pools. Such structures are built of rock or hardened earth, and the lamas or monks do little to provide for themselves beyond keeping a herd of camels. They depend on wandering shepherds and travellers for their necessities.

There is a third great desert area north of the equator, in the Western States of America. This region, which includes S.E.

Photo: C. P. Skrine

Struggling forward against biting wind and drifting sand

Members of an exploring party crossing the arid ridges of the Takla-Makan on their way towards Khotan

California, S.W. Arizona and western Nevada, has a very low rainfall and, being an enormous plateau sheltered by the western coastal ranges, is largely arid. Sections of grassland and mountain ridges divide the plateau into several distinct deserts.

The most westerly is the Mohave, which reaches to within fifty miles of the film city, Los Angeles. It consists of parallel ranges and intervening desert valleys. The air here is wonderfully stimulating although there is a tremendous drop from day to night temperatures.

The white-tailed jack-rabbit, sage-hen, sharp-tailed grouse and grasshopper find a home in this barren country. Amongst the scanty flora are various kinds of cacti, those ugly plants which exist by storing water in their thick fleshy stems and reducing their leaves to mere spines. Some varieties have the appearance of small green prickly balls lying in the sand. Others tower up taller than a man on horseback and even render travel dangerous, since their great needle-like spines penetrate thick clothing and leather.

In other desert sections grows the sage brush, a branching shrub some three to six feet high, with silvery-grey, bitter aromatic leaves, the buds and young leaves of which provide food for the common sage-hen. Ranging the Mohave desert are herds of wild jackasses, descendants of Spanish asses which were turned loose in the region 300 years ago.

To the north of this desert is a very low-lying hollow called Death's Valley, which is 276 feet below sea level and is one of the most remarkable physical features of California. The mountains around it are high, bare and brilliant with varied colours. A river, the Amargosa, enters it from Nevada but disappears into an underground "sink." Shade temperatures in Death's Valley have been recorded as high as 134 degrees Fahrenheit, and the valley has the lowest rainfall in the country. One big commercial enterprise

that section of the desert lay, he could not lodge his claim until he had verified the location. A few months later he set out with two companions to stake his claim. Nothing further was ever heard of Smith, although the mummified remains of his two companions were discovered years later, a hundred miles out in the Colorado desert.

Turning to South America we find there two great barren stretches of land, both sparsely inhabited. The southernmost is the Patagonian Shingle desert, which was formed by the rocks, gravel and debris brought down by glaciers from the Andes during the Ice Age. When the glaciers melted, the debris lay scattered thickly over the terrace-like country east of the mountains. Glacier rivers ceased to flow, and the west winds, after crossing the Andes, were dry. Little rain falls even to-day, and the strong wind for centuries has sorted out the smaller rock grains, silting up old river beds and leaving great expanses of rounded pebbles of granite and volcanic rock. Intermittent rivers still flow, while salt ponds are found in the deepest hollows.

Here and there on the rocky tableland are long depressions called bajos, which have become filled with fine sand and soil carried by the winds. The scanty rainfall collects here and provides enough moisture for grass. Ranches are to be found in the largest of these bajos, with windmills for pumping up water.

One may still find, too, small encampments of Tehuelches and other of the original tribes of Patagonia. The Tehuelches were once the dominant race of the region. Even to-day they are magnificent physical specimens, few being under six feet in height.

Silver and Copper Mines of the Atacama

The second great arid region in South America, the Atacama desert, which includes territory in Bolivia, Chile and the Argentine, is inhabited by very modern settlements, for it has some of the most productive copper and silver mines in the world. The Spaniards who came to South America three and a half centuries ago, looking for gold, scarcely penetrated this salty, treeless region to the west, and it was only comparatively recently that the great Atacama treasure-house was opened.

The higher land is known as the Puna de Atacama, and is a broken mountainous region, volcanic in parts and salty in others. In the east a few small streams flow down from the Chilean Andes and help the poor pasturage but are of no commercial value. As is commonly the case with the greater arid regions, the Atacama desert rises to a plateau. This plateau is parched and cold in winter; and although swept by rainstorms in summer, yields only scanty patches of tufted grass for small herds of domestic cattle. Salt lakes and dry salt basins form the only other supply of water.

To the west the plateau falls away into rainless slopes and thence to the sandy plains where lie the famous nitrate deposits. There are actually several of these deposits, each in small, distinct desert areas, but for convenience they are generally grouped as part of the Atacama desert. The nitrate beds are not continuous, and vary in thickness from eight inches to fourteen feet.

The Largest Copper Reserves in the World

In the Chilean portions of the Atacama desert lie the largest copper reserves in the world, which are conservatively estimated to contain £134,000,000 worth of the metal. Immense quantities of high-grade iron ore are also known to exist here, but for lack of coking coal they still lie almost untouched. Lead, cobalt, nickel, borax and guano are found in and exported from this small but wealthy strip of desert.

Though so barren, this area must have been inhabited for a long period. Explorers have come across textiles, coarse red pottery, and deep pit graves in the course of their excavations. Inhabiting the desert are still a few survivors of a once powerful South American Indian tribe, speaking a distinct language known as Atacameñan.

In a depression of the great plateau of South Africa there lies a vast arid region, the Kalahari desert—with an area nearly as large as that of the British Isles.

South Africa consists of a tableland with an average elevation in the west of more than 3,000 feet. From Lake Ngami, on its northern border, to the Orange River on the south, spreads the great, red sand plain of Kalahari. Most of the rain falls here in December and April in heavy, short showers. Summers are intensely hot, and in the dry period nights are often very cold. Dust storms are frequent.

Several rivers attempt to flow across the Kalahari, the Molopo and its branching tributaries look quite impressive on a map, but they flow only for a short period of the year. The water is lost by evaporation and percolation into the sand. After heavy rains, mud flats in these river beds become shallow pans or lakes. Earlier travellers

were baffled by the fact that fish suddenly appeared, apparently from nowhere, after these heavy rains. It was discovered that in the drying river the fish burrowed into the mud before it hardened and emerged quite brisk when the rivers filled again.

The dry river courses are easy to trace, as the red sands bordering them have lost much of their pigment and become a white fringe. But water can usually be found not far below the surface in the beds of the larger rivers, though it is generally brackish. The original inhabitants, the Bushmen, still to some extent live and hunt in the grassier parts. They depend upon this underground water for their existence, and use hollow reeds, fitted one within the other, to suck up the precious liquid.

Most of the Kalahari sand dunes are covered with knee-high tussocks of grass, about fifteen inches apart. Quite large areas, too, are clothed with scrub and quick-seeding plants like everlasting flowers; while a variety of wild animals, birds and insects wander over the region. The ostrich and bustard, lions, antelopes, hyenas, jackals, poisonous snakes, tarantulas, white ants, and mosquitoes all exist on the Kalahari. Northwards the desert merges into grassland proper, and there are found giraffes, rhinoceroses, elephants, and other big game.

Where the Kalahari borders the Atlantic in the west, the cold sea currents cause fogs as they do with the Sahara farther north, and many travellers and mariners have lost their lives along the dangerous coast.

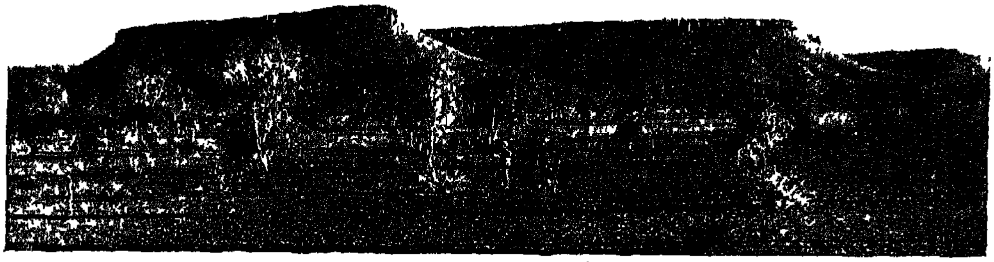
There is one small desert, the Namib, lying to the south-west, which has an even drier climate than the Kalahari. Its rainfall is only from one to five inches a year, the driest in South Africa. The desert is a strip running parallel with the coast to Oliphant's River, and is from eighteen to thirty-five miles wide. The long gravel plains of the Namib can only support a species of ice-plant, lichens, and the strange, mushroom-like Welwitschia.

The Australian Deserts

Following the line of the Namib, on latitude 30 degrees south, and progressing eastward on a globe, we come to the great Nullabor plain, bordering the Great Australian Bight. The rainfall here is moderate,

Photo: R. Nash

The desolate Namib desert, on the edge of the Kalahari, is the driest spot in the whole of South Africa and looks it. Only a few hardy plants can eke out a desperate existence here



Courtesy of the Australian National Travel Association

Parts of the so-called desert of Central Australia are not so barren as is generally supposed. In the district near Alice Springs, the soil is extremely fertile and after rain the grass can be "seen" growing. Note the flat-topped hills, the summits of which indicate the original level of the land

but where the plain peters out at the edge of the arid hinterland there have recently been discovered limestone caves containing natural wells which for centuries must have supplied the natives with water. The district has always been regarded with awe by the superstitious natives because the wind bellows up through holes in the limestone and makes weird moanings.

From the Nullabor plain the land gradually rises to the interior plateau, which stretches drearily almost from south to north of the whole continent. Ages of wearing by wind and dust have exposed bleak scarps of the harder granite rocks. They are not mountains in the true sense, although they sometimes reach 4,000 feet in height. But between these scattered higher lands the desert undulates monotonously from ground swellings to wide, salt-floored flats.

The intense dryness is due to the position of Australia between the two main rain belts of the southern hemisphere. The hot summer winds are trying, and the unevenness of the heat often causes "air pockets" which are a danger to the aeroplanes that cross the dreary tracts of desert and scrub.

The physique of the Australian natives is considered by ethnologists to have adapted itself to desert conditions. They have thin, muscular bodies and their eyes are deeply set to protect them from the glare of the sun. Living things are found only on the edges of the desert, where salt bush and prickly spinifex grow. There are kangaroos, jumping ants, grasshoppers and, since they were introduced in 1862, millions of rabbits. The rabbits are a menace, not only because they eat food that should go to the sheep, but because their warrens are steadily destroying plants and extending the area of desert.

Gold was discovered in the middle of the 19th century by prospectors reaching out from Western Australia, and is still being worked. Richer deposits are known to exist farther out in the desert, but the lack of food, water, and transport, as well as the unfavourable climate have hitherto defeated attempts to exploit them. With the development of the aeroplane, however, there is every prospect that the desert will soon be forced to yield up its riches.

CHAPTER XXII

FERTILIZING THE WASTE LAND

IN early ages when the world was only sparsely inhabited, Man could select the more fertile areas in which to make his home. But, with the passage of time, as the numbers of human beings increased and they and their flocks needed more food and pasture, areas less and less fertile had to be utilized. Strong peoples drove weaker tribes to the very edge of the deserts where they had to use every ingenuity and artifice to coax grass, grain and fruits from the parched earth.

History has left us no definite record of the first people who watered their crops when the rainfall was scanty, but it is evident from the

remains of primitive contrivances and canals that irrigation was practised many thousands of years ago in several widely scattered places in the world.

South American Indians of Peru and Chile still use ancient canals which yet bring water from the rivers to the desert regions. Some of these canals are 400 to 500 miles in length and represent wonderful engineering feats for those ancient times. Yet side by side with them, other crude and primitive methods still persist to-day. The squaws in the Arizona dry lands sling a great waterpot on a post as their ancestors did, so that the drips from the small hole beneath water a patch of onions.

It is Egypt, however, that seems to have been the great home of irrigation even as long ago as 2000 B.C. Paintings and sculptures of that period show the peasants baling water by hand for the thirsty fields. The annual floodings of the great river Nile as it flowed through desert land had left, in the course of centuries, a narrow strip of fertile sediment bordering the river. The Egyptians must have quickly realized that when the floods were low they could artificially supply water to the land just out of flood-reach and still obtain good crops. But baling by hand was a slow and laborious process. Inventive minds set to work and primitive mechanical aids replaced hand labour.

Primitive Devices for Raising Water

The Egyptian shadhoof and Indian denkli, the sakia and Persian waterwheel and Archimedes' screw were all produced some two thousand years ago. Yet even to-day, in all artificially-cultivated arid country lying away from the modern irrigation basins, these devices are in constant use.

The shadhoof consists of two rods crossed above a well or stream. Over their meeting point is balanced a long pole, its heavier end weighted with clay lumps or rocks, and on the thin, tapering end is hung a leather bucket. The lighter end, which tilts skywards when at rest, is pulled down by a rope till the bucket dips in the water. The rope is released and the counterbalance swings up the filled bucket. One shadhoof worked by hand can irrigate about four acres.

The various forms of waterwheel are worked by cattle; in one common type a pair of oxen is yoked to a horizontal beam, which turns a wheel lifting an endless chain of buckets or clay pots from a well or stream. When the filled buckets reach the top they tilt the water into a small canal leading into the fields. About six to twelve acres can be thus constantly irrigated.

Our word river comes from "rivus," a Latin one meaning a brook or stream, those who used the same stream were called "rivals." In Europe from Roman times much of the prosperity of the agricultural regions depended on irrigation.

Wind power was extensively used and the energy of a running stream was employed to turn a wheel and raise some of its water for irrigating nearby lands. It was not, however, until steam power was developed that any great advance was made in irrigation. Thereafter the windmill was largely displaced by the steam pumping engine; to-day the small and compact internal combustion engine is enabling farmers far from electric power lines to do their own pumping, and is extending to the remotest quarters the advantages formerly available only to those whose lands lay near great cities. Electricity is rapidly becoming the cheapest source of power and is carried hundreds of miles on overhead cables. With its wider availability, greater possibilities than ever are opened up for fertilizing thirsty lands. Already in the Sudan, in the western United States and in India, the desert "blossoms as the rose."

The valley of the Nile, including both Egypt and the Sudan, is perhaps the most interesting of all those places in the world where desert has been and is being irrigated to produce food and the raw materials of clothing. The river runs through absolutely barren desert and it is only because the Nile and its tributaries rise far to the south amongst mountains with a heavy rainfall that the well-replenished waters can flow constantly through tracts of parched sand to the sea.

In Egypt the river banks are low and, after the rainy season in the far-off mountains, the swollen waters flood the surrounding strip of land. For thousands of years this flooded ribbon along the Nile has yielded crops, and on each bank a strip of fertile land, built up by the repeated deposits of river silt, has been reclaimed.

First Modern Irrigation Schemes in Egypt

"There is too much Nile water flowing out to sea," said engineers, agriculturalists and politicians eighty years ago. "Much more water could be diverted over the arid soil and crops could be grown on the waste land." As a first step the ancient canals of Lower

Egypt were deepened, but every flooding of the river filled them with silt. The Khedive then gave to the French engineer Mougel the task of designing a weir or barrage across the river. Two adjoining barrages were built in 1861, one over the Damietta fork of the Nile and the other over the Rosetta fork, about twelve miles north of Cairo. The river, in flood time, could pass over the weir; but when it was low, the water piled up behind the barrage sufficiently high to flow into the network of canals upstream and thus to irrigate the fields of Lower Egypt. Unfortunately these barrages were not strong. So, in 1884, Sir Colin Scott Moncrieff, a British engineer, extended the masonry platforms and erected subsidiary weirs immediately downstream.

Upper Egypt, until 1900, had made use of the Nile waters only for what is termed "basin irrigation." In that system a large area of land, sometimes as great as 50,000 acres, is surrounded by an earth embankment, into which is led a canal from the river. Water is flooded over this basin to a depth of three or four feet. As soon as it has drained away, crops are planted which need no further watering before being harvested. This served very well during a brief crop-period following the Nile flood season, but the ground for the rest of the year lay idle.

At the end of the 19th century the Khedive Ismail had acquired great estates in Upper Egypt and determined to grow sugar-cane. But although he had built a grand canal flowing parallel to, and west of the river for 200 miles, it could not fill up during the low-river season, and the sugar-cane crops were not very successful. So a barrage some half-mile long was built across the Nile at Assiut to hold up water to feed the canal during the summer or low-water season.

The work was finished in 1902, having taken four years to build, at a cost of £800,000. The Nile flood of 1902 was unusually low and the engineer in charge of the newly-completed barrage decided to close the gates between the piers and head up the flood as in a proper storage dam. When sufficient water for both winter and summer irrigation had been conserved, the river was allowed to flow freely down to the lower reaches. This practice has been continued at Assiut every low flood, and the basin lands around can thus grow their crops of cotton, millet, maize and sugar-cane quite independent of the vagaries of the Nile. In 1936 the dam was strengthened and a concrete apron built on the bed of the river.

Courtesy of the Egyptian Travel Bureau

Forming a beautiful and regular pattern—water foaming through the sluices of the Aswan Dam. The benefits accruing to Egypt from the construction of this great storage dam have been incalculable

Since Assiut Barrage proved so successful, others at Esna and Nag Hamadi were built; as a result Upper Egypt was freed from the fear of crop failures due to lowness of the Nile floods. With such an increase in the area of land utilizing the Nile water each year there came another problem. In some years the flood level of the river was so low that by the time the various irrigation schemes along the course of the Nile had taken their supplies, little water was left to flow into the sea. If still larger areas were to be watered

then a storage dam must be built, for safety in low-level seasons.

For years the idea was discussed and finally Sir Benjamin Baker, K.C.M.G., and two other eminent engineers—M. Boule, a Frenchman, and Signor Torricilli, an Italian—drew up a preliminary scheme. A new site was chosen above Aswan at the head of the Nile's first cataract. The river here flowed through a bed of hard, red, granite-like rock, called syenite, which could safely take the estimated pressure of 1,000 million tons of water. So a vast reservoir was built, the masonry of which also was syenite, taken from neighbouring quarries worked since the time of the Pharaohs.

Aswan Dam is 6,400 feet long, or about one and a fifth miles, and the "back" of water it impounded extended for 140 miles upstream. It was soon found inadequate; and the dam, in 1907–11, was taken up another twenty-three feet, giving a head of 153 feet of water. The extra cost was £1,500,000, just about half the original sum spent on construction. Engineers calculated that when water was let out of the 140 "under" and forty "upper" sluices, the powerful flow down the dam-front would be so tremendous that the "toe," or bottom of the slope, would soon be worn away. So covering aprons and toe protections were built. With the extra height, the dam impounded about one and a half million acre-feet, or about double its former amount. In 1929 further heightening was found necessary and the dam was raised 29ft. 6in.

No single irrigation work of modern times has been more useful or far-reaching in beneficial results upon agricultural and industrial welfare than the Aswan Dam. The 1913 flood was the lowest for 150 years and, but for this dam's storage water and that impounded by the many barrages along the Nile, there would have been terrible famine and an economic collapse in Egypt.

Irrigation in the Sudan

Though we think of Egypt as the "land of the Nile," only about one-third of that river's length is in the country of the Pharaohs. For the earlier part of its course it flows through the desert and semi-desert areas of Nubia or the Anglo-Egyptian Sudan, which had never been so intensively cultivated as Egypt. What water the inhabitants required for their crops they obtained by using waterwheels. In 1909 an experimental farm was opened near Khartoum, the capital of the Sudan. New irrigation canals were dug and cotton grown. The yield was highly satisfactory and plans were made to extend the area under cultivation. Sudan is the home of the long-fibre Egyptian cotton, but up to that time no great quantities had been grown.

A British joint-stock company, called the Sudan Experimental Plantations Syndicate, entered into an agreement with the Sudan government to develop about 100,000 acres of land in the almost barren Gezira plain, at the junction of the Blue and White Niles. The Great War held up construction of a new dam, five miles south of Sennar, but by installing new pumping stations the area under cotton was increased to 22,500 acres.

By July, 1925, the dam was built at a cost of £6,000,000 and an extensive system of canals costing a further £3,000,000 was dug. The Sennar or Makwar Dam functions both as a dam and a barrage. It enables the ordinary river supply to flow on to the lower reaches of the Nile, but stores 600 million tons of water, more than sufficient to meet the demands of the Gezira cotton, lentil and bean crops in the dry season.

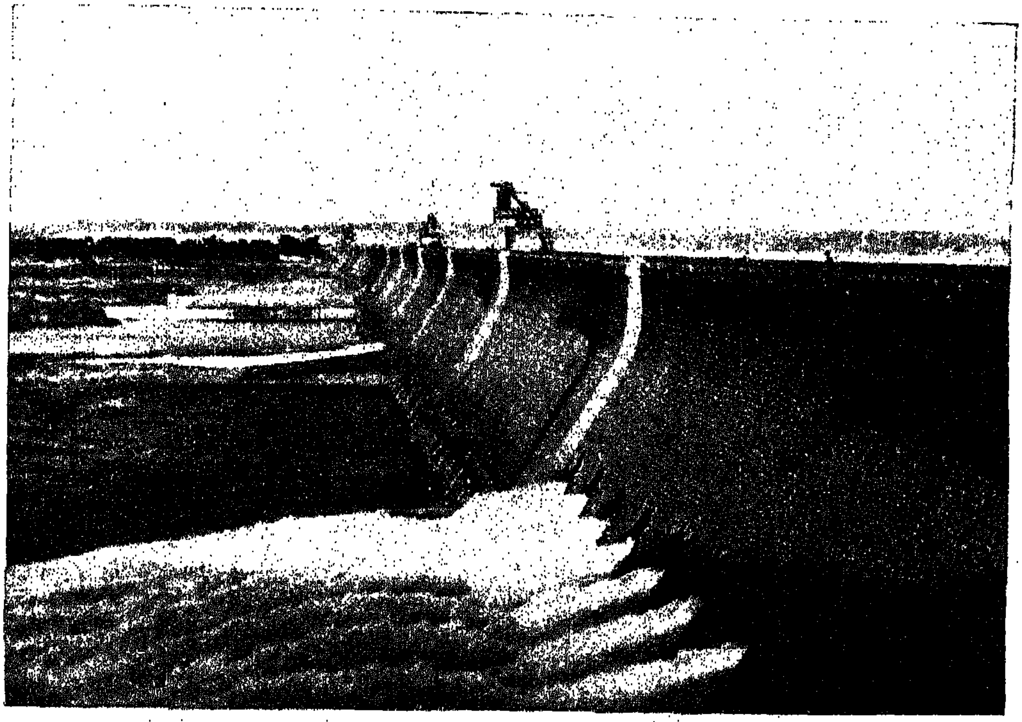
The main canal leading from the dam is about 36 miles long before the waters it carries are branched off for irrigating. The area cultivated by the Sudan Syndicate alone in 1929–30 was 150,000 acres. Actually the Sennar Dam now stores sufficient water to irrigate an area of more than twice that acreage, and further extensions are being planned.

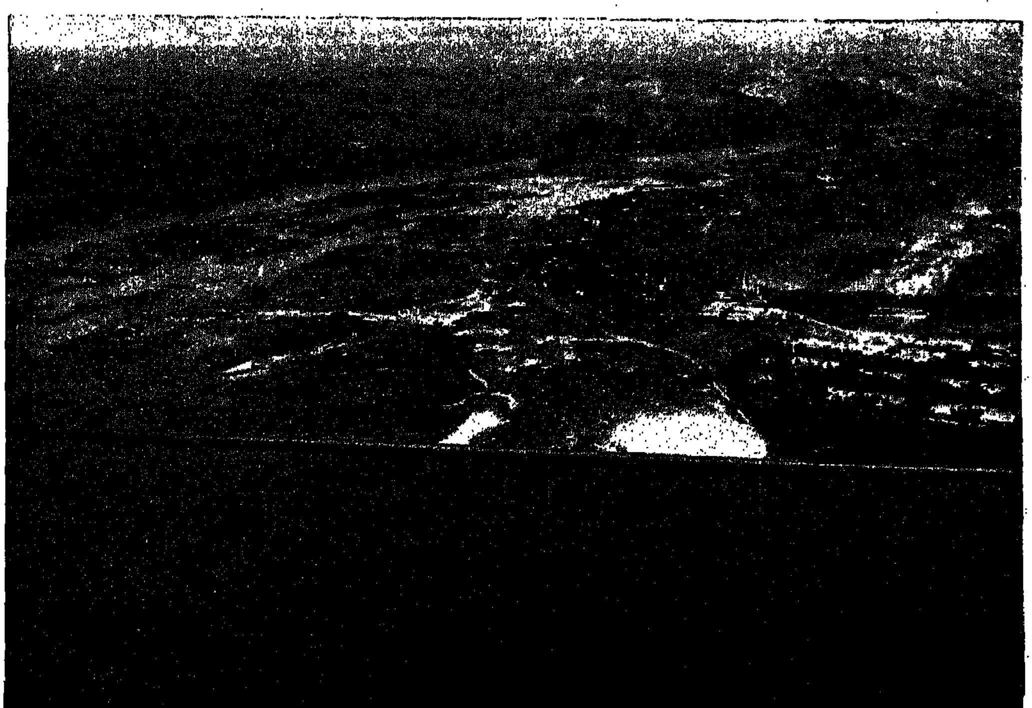
Irrigation in Abyssinia

Other irrigation schemes have been put in hand for several of the desert plains of the Sudan. Chief of these is at Tokar, where the chocolate-coloured flood of the Barakat from Abyssinia spreads a thin coating over the Tokar plain. Canals to control the direction of the flow have brought the waters to the cultivated areas, whereas formerly they were wasted on barren sand.

Along the Sudanese banks of the River Gash, which rises in Abyssinia, the control of the floods has resulted in bumper cotton harvests, greatly increasing the prosperity of the inhabitants. The overflow of the river used to flood the plain of Kassala to such an extent that none of its water reached the Blue Nile during high season. Constant progress in irrigation work and in canal-making is going on to-day in connexion with the Gash.

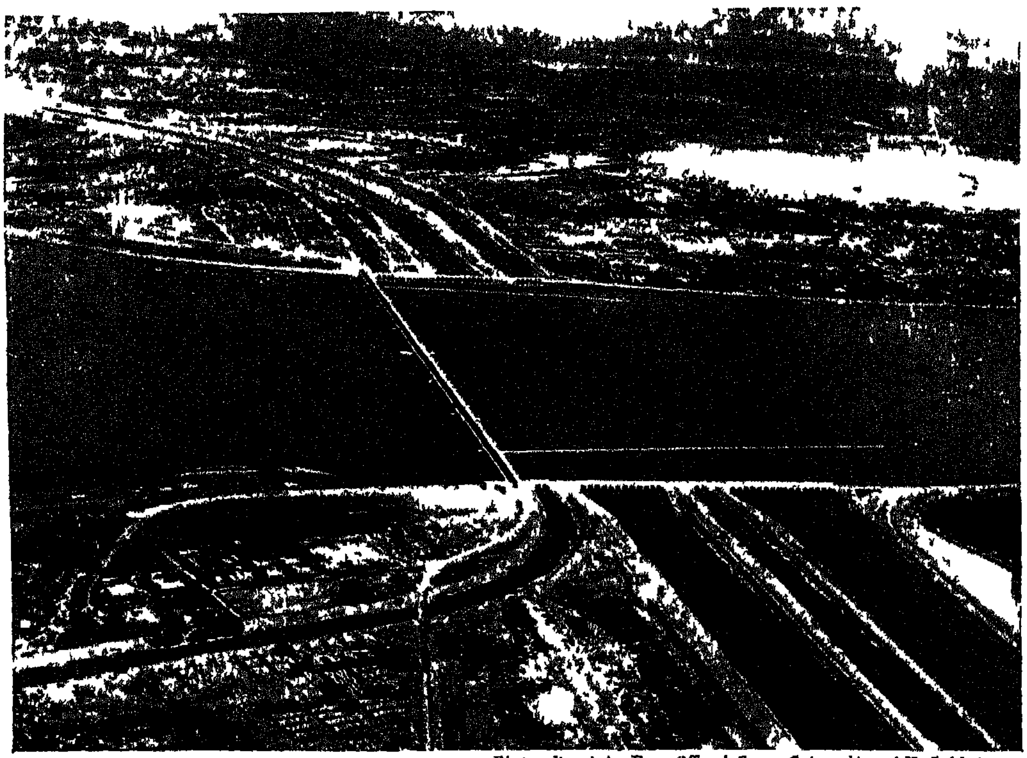
The problem of the fertility of the irrigation water is one that is occupying agronomists





Photos: American Colony, Jerusalem & Egyptian Travel Bureau

Some idea of the vast quantity of water impounded by the Aswan Dam may be gained from this photograph taken from an Imperial Airways liner. Note, also, the width of the dam (approx. 1½ miles) in comparison with that of the Nile beyond. *Top:* A side view of the dam before it was heightened a further 29 ft. 6 in. in order to increase the amount of water stored



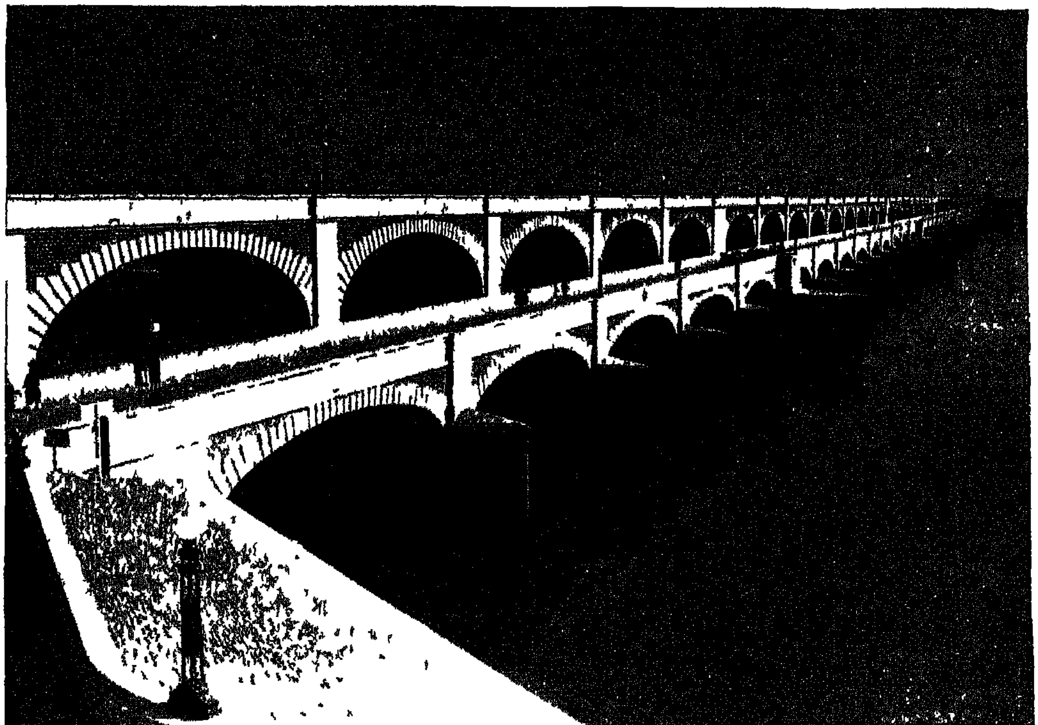
Photos Royal Air Force Official, Crown Copyright, and H J Shepstone

The huge Sukkur Barrage across the River Indus seen from the air during construction and when completed in 1932 In the view from upstream (*top*) taken in 1931, the coffer-dams erected for the building of the divide walls (*see below*) are clearly shown on both banks, as are the irrigation canals and their head regulators in the bottom photograph. (*See also illustrations on following pages*)

very seriously. The Nile, as we have seen, is a great silt-bearing river, and on this account the water impounded by the Aswan and Sennar Dams has to be taken from the November flows when the water is clearest, otherwise the silt would choke the dams and render them ineffective. "But," the reader may ask, "does this mean that the cotton lands will suffer, for lack of the fertilizing silt?" That remains to be seen. Certainly the yield per acre has dropped in recent years. On the other hand, two more factors have to be considered, the cotton is grown year after year on the same land without rest or rotation, and less fertile areas are now being cultivated, thus lowering the average yield.

The Italo-Abyssinian war caused the temporary suspension of other important Nile utilization schemes, that were under discussion between the British, Egyptian and Abyssinian governments. One for the building of a dam at Lake Tana, in north Abyssinia, has been accepted in principle for some time past. If constructed, this dam will conserve to the full the waters of the Blue Nile.

In India, too, irrigation has been practised extensively for many centuries; and to-day great barrages and dams are reclaiming desert land and preventing the periodic famines that since time immemorial have taken their heavy toll in human lives. Any failure of the monsoon winds to bring their normal supply of rain to India at the end of the summer caused immeasurable hardships to the peasantry, for the soil in this semi-tropical country cannot hold sufficient water to serve the crops during the dry months. For centuries waterwheels and other crude irrigating devices had been the only palliative, but the year 1885 saw the beginning of a new era in the conservation and distribution of flood water. For the next forty years successive new developments took place. By 1923–4, 28 million acres were under irrigation in British India alone, and later schemes have brought the total for all India to nearly 50 million acres.



Courtesy of the Indian Railways Bureau

Notable as an architectural as well as an engineering feat—the Sukkur Barrage from the south, at low water. The pleasantly designed carriage-way stands 17 feet above the highest flood-level

By far the larger amount of the irrigation water is still supplied from tanks, wells and annual inundation channels. This is to some extent unavoidable, since India has only two rivers at all comparable in size to the Nile. These are the Indus and Ganges, both rising in the Himalayas. The Ganges lies in a

great plain with a fairly satisfactory rainfall, but in order to assist crop growth in the hotter and drier times of the year, irrigation channels draw upon the river water.

The Indus flows through Sind, a district in the north-west of India. The rainfall here is scanty: in Upper Sind it is often no more than three inches a year, and in some years no rain at all may fall. Between the Indus and the Ganges lies the Thar desert, a sandy, uninhabited region which is out of the path of the wet monsoon winds. But worse than the scantiness of the rainfall in Sind is its irregularity. Although the people there from time immemorial have practised water storage, and have dug an extensive system of canals, repeated crop failures in bad monsoon years showed that more permanent irrigation works were needed. The canals either became choked by the silt-bearing Indus water, or else the banks were eroded when high-level waters flooded the countryside, as they often did for some fifty miles on either bank.

The Indus has an average width of a mile; and Colonel Walter Scott as far back as 1847 declared that such a volume of water could be controlled only by a solid weir or barrage. But various subsequent commissions of investigation either considered the cost of such a structure too great, or thought its construction not a pressing enough necessity, and the plan was shelved. Constant improvements in the canal system itself went on, however: canals were given new heads that prevented excessive inundation of silt-bearing water; new channels were dug on the better slopes to aid the natural flow, and the general network was extended.

The Gigantic Sukkur Barrage

The government of the Bombay Presidency, which controlled Sind, was still dissatisfied and in 1910 submitted a scheme for constructing a barrage upstream of the rocky gorge at Sukkur, where it would be founded upon rock. Again the proposal was turned down, on the grounds of it needing too great an expenditure. But when, in 1916, a revised scheme was tabled, detailing the proposed enlargement of the irrigation area and the provision of a permanent water supply, the Government of India agreed to it. The successful accomplishment of the undertaking was largely due to Mr. A. A. Musto, C.I.E., to whom was entrusted the preparation of the final report and the design of the barrage. In 1918–20 he re-designed the whole project, and work began on the Sukkur Barrage in July, 1923. The barrage was actually built three miles below the Sukkur gorge, and a scheme was included for a system of canals to be fed from the Sukkur reservoir.

The base of the barrage is a wide masonry floor founded upon sand. Built upon this floor are fifty-eight piers each ten feet thick and sixty feet apart: and seven twenty-five-feet abutment piers, one placed between every nine of the smaller piers. The sixty-feet sluiceways are provided with gates to raise the water-level to that required for full supply. A railway, on which runs a three-ton locomotive crane, crosses the downstream arches; it pulls six trolleys on which is mounted electric machinery to lower or raise the gates. The whole of the sixty-six spans can be closed in one and a half hours when sudden fluctuations in the river-level make it necessary. A carriage-way, seventeen feet above the highest flood-level, and two footways totalling a width of twenty-three feet, cross the upstream arches. The arches are of concrete, but the superstructure is built of masonry faced with hard, creamy-white limestone.

Lord Willingdon, Viceroy of India, officially opened the barrage in January, 1932; it is often called the Lloyd Barrage, after Lord Lloyd, a former Governor of Bombay. The total cost, including 5,169 miles of canal excavation, was about £15,000,000. Three great new canals, each as wide as the Thames at London, take off from the right bank upstream and four from the left. They irrigate an area of 5,010,000 acres. About 3,500,000 acres of this land had previously been unirrigated and uncultivated land. Irrigation water from the reservoir will be available for main crops two months earlier each year than before.

It is estimated that by 1962, 2,440,000 acres of wheat, 790,000 acres of cotton, and 695,000 acres of millet, besides other produce, will be cultivated. This is the maximum possible with the present irrigation works. In 1929–30 only 287,000 acres of wheat, 326,000 acres of cotton and 1,015,000 acres of millet were produced in British Sind.

Crop rotation must be carefully watched if crops are now to follow one another all the year round. Fertility used to be maintained by a "fallow" or resting period for the soil. Now, such restorative crops as ground-nut, berseem and pulses alternate with those taking much nutriment from the soil. Crops, like sunn-hemp and indigo, to be ploughed in for their manurial content, are now grown more frequently and it is hoped to introduce

A remarkable transformation from parched mud-flats to a vast sheet of flourishing wheat. Johi Pat, in the Southern Dadu division, before and after the functioning of the Sukkur Barrage irrigation canals, one of which can be seen on the right of the bottom photograph. Harvesting is in progress in the far distance

some mixed farming when the new irrigated fields are well established.

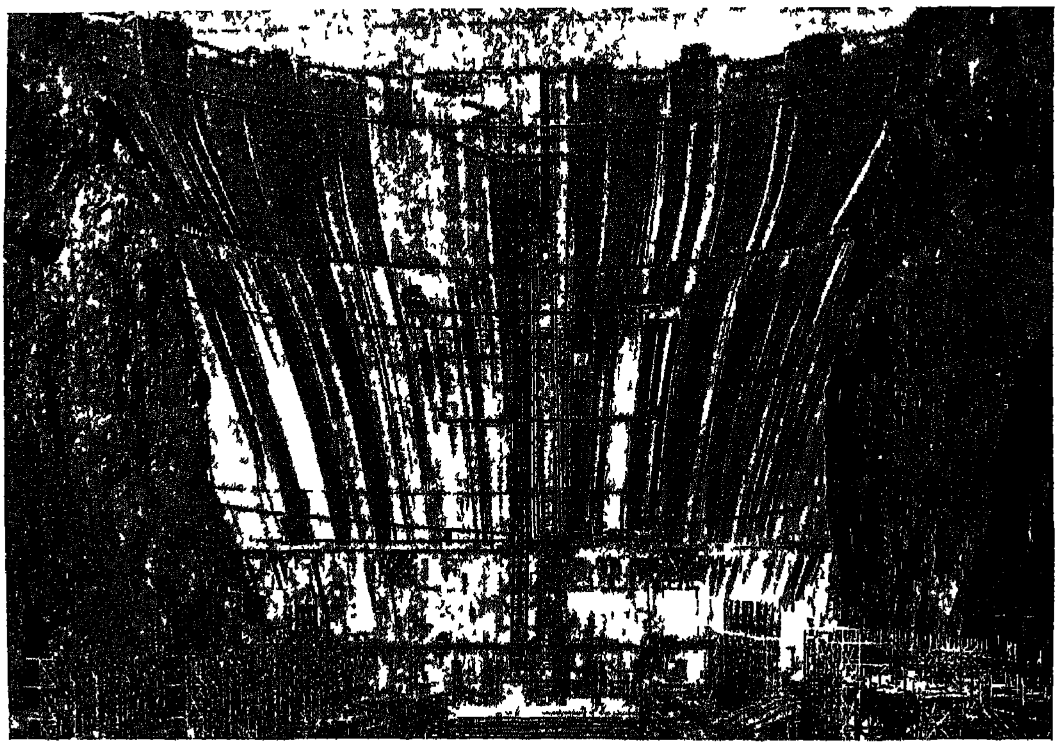
The Sutlej Valley Scheme

North of British Sind lies the Punjab—watered in part by the Sutlej, a great tributary of the Indus. In 1926 four weirs were completed, one on the Chenab River and three on the Sutlej itself. Twelve main canals distribute enough water held back by these weirs to irrigate 5,000,000 acres. Three and a half million acres of this land, which was previously barren desert, are now producing grain together with lentils and other pulses.

The only other irrigation work in India which can approach in magnitude the Sukkur Barrage and Sutlej Valley schemes is the Mettur Dam in the southern State of Mysore. This project, designed by Colonel Ellis, was held up because of the Great War, but after ten years of river measuring a start was made in 1925. The dam cost £4,500,000 to construct, the cement alone costing £700,000. The dam's main task is to alleviate sudden river floodings rather than, as at Sukkur and Sutlej, to pile up water for canal flows. A knighthood was conferred on Clement Tudway Mullings, C.S.I., the chief engineer on the project from 1927–31.

The dam was officially opened in 1934 and forms part of the Cauvery Reservoir scheme. The Stanley Reservoir above Mettur saved the 1933 crops when the north-east monsoon failed to bring rain. Electric pumping from wells sunk along the river margin has been initiated to irrigate other arid areas in Mysore.

The Deccan also has a most precarious rainfall and water-storage has been practised for centuries as a stand-by in case of drought. Tanks are found in every village, some hold enough water to irrigate only ten acres, whilst others are in reality great lakes. Inscriptions on two great tanks in Madras, which still irrigate two to four thousand acres, prove them to be over 1,100 years old. The most common practice nowadays is to dam up water during flood-time to form a storage lake near the head of the comparatively short river valleys. This water is released in the dry months as required. Fifty miles or so downstream there will be a "pick-up" weir which piles the water to a sufficiently high level for it to run off into the irrigating canals.



H. J. Shepstone

Boulder Dam, which holds up the River Colorado in Black Canyon, in the course of construction. The crest of the dam is 727 ft. above bed-rock, and 3,250,000 cubic yards of concrete have gone to its making. *(See also illustrations in Chapter XII)*

Such a dam is the Nizamsagar, which was opened in Hyderabad in March, 1935. It is forty-nine square miles in area and supplies water from its nine deep sluices to four weirs lower down the river Manjra, each carrying automatic flood-gates. The Nawab Ali Nawaz Jung Bahadur undertook the project, which was carried out by Mr. C. C. Paul, M.I.E.

During recent years many great irrigation schemes have been undertaken in the United States of America. Particularly notable are its concrete storage dams, and the mechanical devices for distributing the water. The greater number of such works are to be found in the arid and semi-arid Western States Settlers were slow to migrate to these regions because of the scanty rainfall. For centuries the hand irrigation of the Indians and their Spanish conquerors was the only means of supplementing the meagre rainfall. It was the zealous missionaries who first established modern irrigation canals in America, especially in California. Hailing from France, Spain and Italy, where intensive irrigation is carried on even in fairly well-watered districts, these priests showed the poor settlers how to utilize water supplies and grow crops on the desert itself.

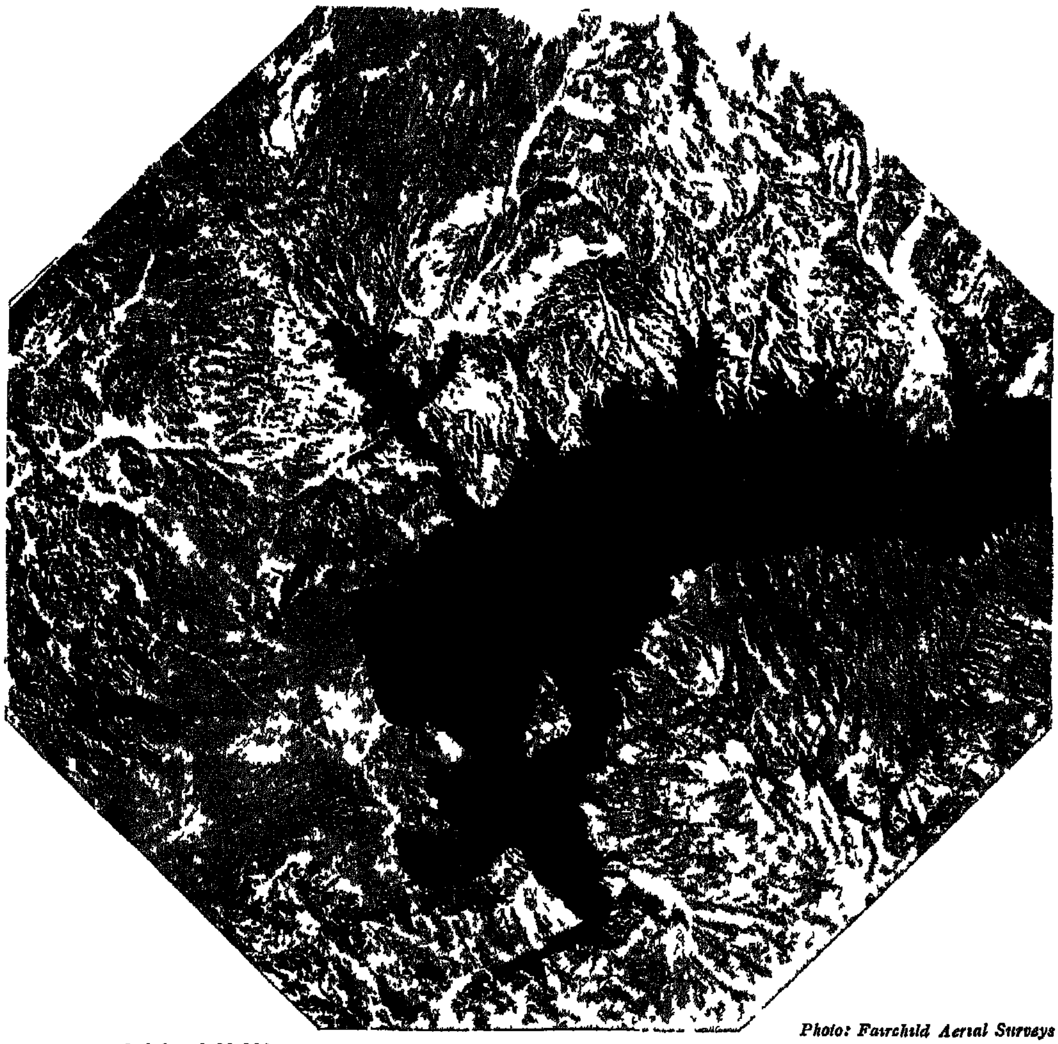


Photo: Fairchild Aerial Surveys

Taken from a height of 20,000 ft.—a wonderful vertical air photograph of the 145,000 acre reservoir formed by the Boulder Dam. An area of over 200 square miles is covered in this view and the dam itself can be seen as a minute semi-circle at the bottom of the photograph. The special camera with which the picture was taken exposes ten negatives simultaneously, producing the overlapping octagonal print seen above

Salt Lake Valley lay utterly neglected because of the intense salinity of the soil,

until the Mormon pioneers settled there in the middle of the 19th century. They brought the water of City Creek by canals to their crops, and the wilderness produced sufficient for their needs. The settlers, however, were not wealthy enough to build large barrages and dams for their crops; but government schemes were brought forward, and large land and water corporations put up the capital for building the costly works. In 1919 about 20,000,000 acres of land were irrigated in the United States. Since then, many new dams have been built, old ones reconstructed, new drainage systems employed and canals extended. It is estimated that by irrigation a total of 63,000,000 acres of desert and poor land can be made to grow crops.

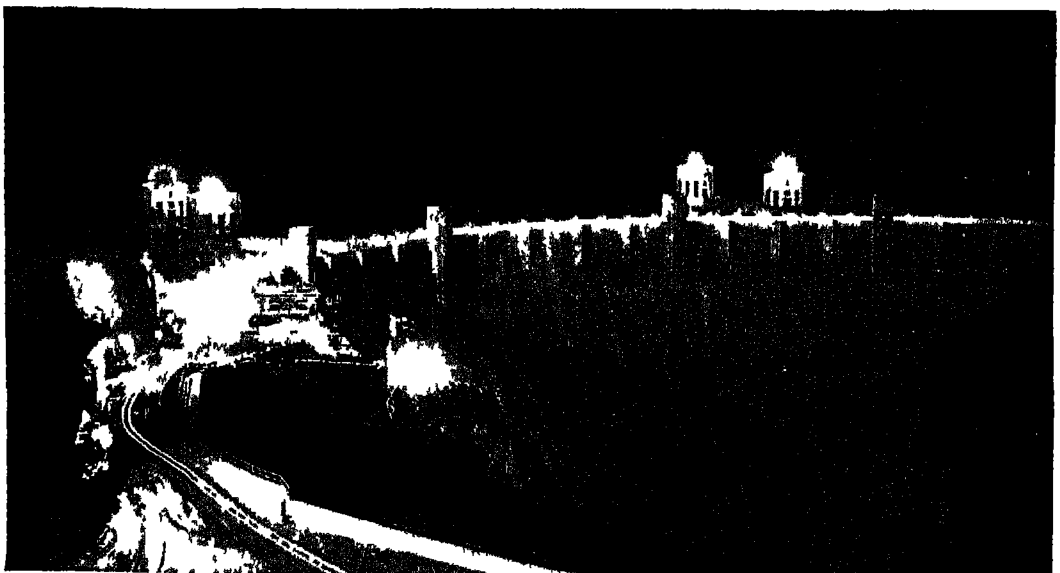
Great projects are now in progress on all the big rivers in the United States. The Grand Coulee, the world's largest dam, is being erected on Columbia River in Washington. Over 1,200,000 acres of desert will be fertilized when this work, begun at the end of 1934, is completed. The dam will be 512 feet high above bed-rock. The crest of the dam is 4,100 feet long, about 600 feet less than the crest of Sukkur Barrage. The Coulee Dam is to provide power, as well as water, for 30,000 highly modernized, fully electrified forty-acre farms within its irrigation basin.

Besides the enormous lake that will be impounded, a separate reservoir, 310 feet above the level of the dam, is being built to supply irrigation water. Twenty giant pumps, each of 33,000 horse-power, will lift the water from the dam through a two-mile long canal to fill the reservoir. An immense conveyer several miles in length has been constructed to haul sand and gravel from the pits to the largest sorting and washing plant known. To protect the rock at the toe of the dam from erosion by the enormous flow of water over the spillway, a deep pool is to be provided.

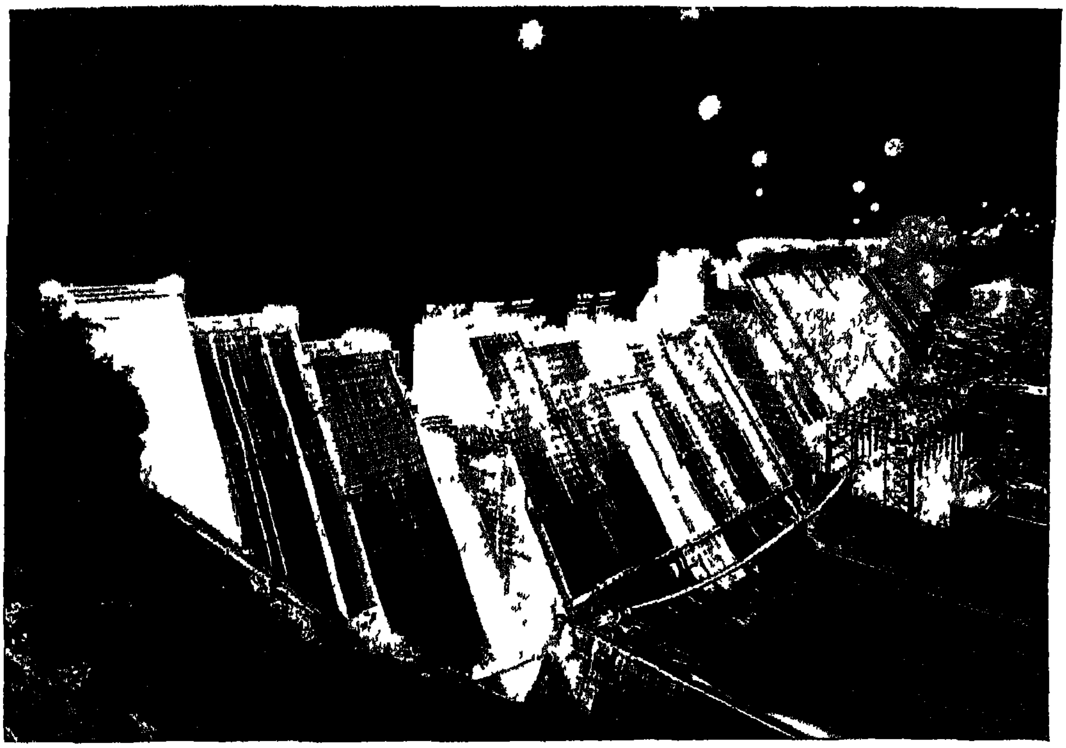
The bustling Americans have an interesting sideshow in connexion with the building of the dam. Mason City, a temporary township to house the workers, is being used as an experimental field laboratory for testing out electrical service for domestic use. Long before the full scheme for utilizing the Columbia River is finished, electricity will be employed in that region for every conceivable task—domestic, industrial and agricultural.

In March, 1935, a great dam was put into operation as part of a scheme to utilize the water of the Colorado River in California. This, the Boulder or Hoover Dam, impounds a lake 115 miles long with an area of 145,000 acres. The work was begun in 1931 and it is expected to take six years to complete, including the construction of the All-American canal taking off from Imperial Dam, higher up the river. Imperial Dam already irrigates great fruit farms in Imperial Valley, and a further million acres will be irrigated by the new canal. This dam and canal are a pressing need, for the 1934 drought ruined £1,000,000 worth of crops in the valley.

As long ago as 1905, an American engineer, A. P. Davis, conceived the idea of constructing



The 1,180 ft. long crest of Boulder Dam is traversed by an inter-state roadway, here seen with the night-lighting scheme in operation



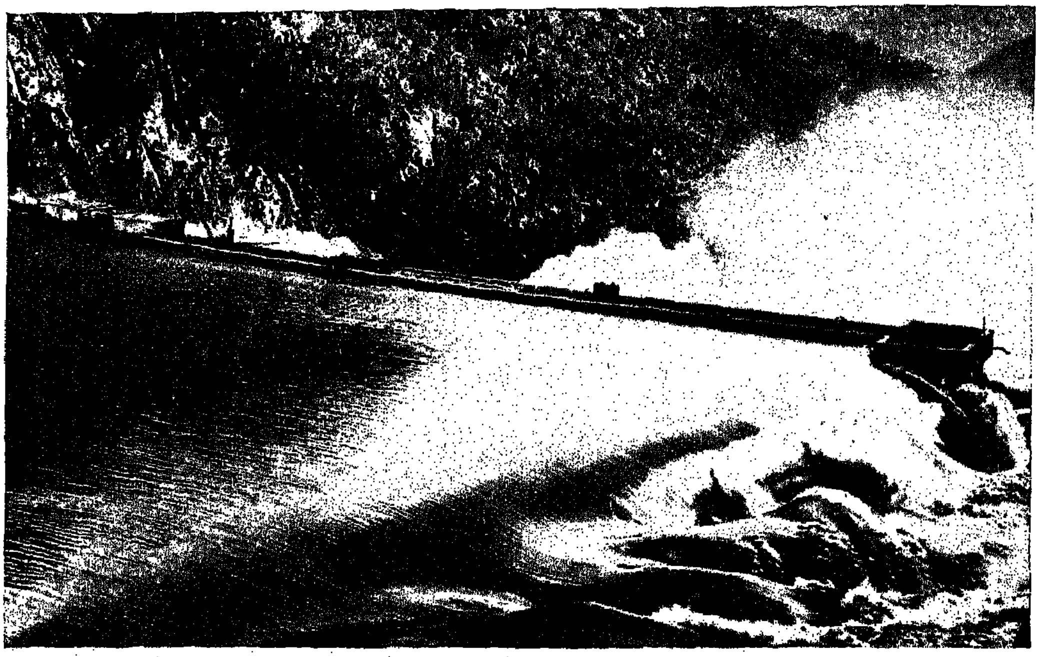
An extraordinary view of the Norris Dam floodlit while work was proceeding during the night. The dam, which is on the Clinch River, is part of a big irrigation scheme for the valley of the Tennessee River

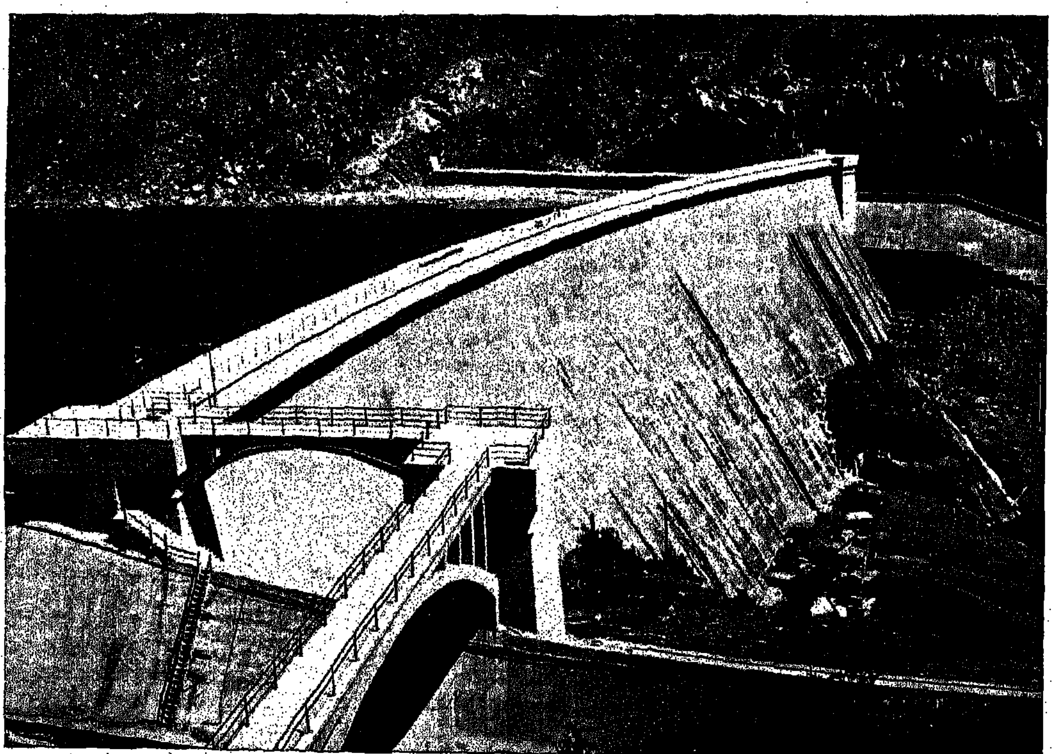
such a dam in the Black Canyon where the walls of the gorge rise 800–1,000 feet in the midst of the desert. President Hoover was much attracted to the scheme some years later, and his interest made the enterprise possible. The construction was put into the hands of F. T. Crowe, an engineer of wide experience in dam building. Since the river narrows in the Black Canyon gorge, its height is greater there, and a dam with a crest 1,180 feet long and towering 727 feet above bed-rock had to be constructed: the famous Woolworth building in New York, if stood on the river bed, would only just overtop it.

Great care had to be taken in pouring the five and a half million barrels of cement for concrete, for the whole sides and base of the dam rest on rock, the temperature of which is much lower than concrete. To prevent cracking, pipes containing refrigerated water were inserted temporarily. The engineers have calculated that it will take 150 years for the concrete to cool to the temperature of the surrounding rocks.

Modern machinery saved tremendous labour during construction. It took 1,200 men and machinery less than two years to place a greater volume of masonry than is contained in the great pyramids of Egypt, which are estimated to have occupied 100,000 men for twenty years. The dam itself took over four years to construct and it will be about another four years before the reservoir is completely filled. One hundred and fifty miles downstream from Boulder Dam, Parker Diversion Dam is in course of construction. It is to serve as storage for a 100-mile-long reservoir. In the meantime power for construction work and for lifting water is drawn from Boulder Dam.

The most recent irrigation scheme in the United States is that of the Tennessee Valley Authority, commenced in 1933. The idea is not new. Ever since the days of George Washington engineers have dreamed of harnessing these swift-flowing waters to the needs of man. During the Great War a mile-wide dam—the Wilson Dam—was built on the Tennessee River at Muscle Shoals. It is now incorporated in the new and larger scheme. Although the area to be developed has a moderate rainfall, it has been rather neglected in the past; intensive cultivation by irrigation and the development of new industries should make it an important centre in the near future.





Headwork of a successful Australian irrigation undertaking—Burrinjuck Dam, on the Murrumbidgee River, New South Wales. The dam impounds 771,641 acre-ft. of water and there is now a population of over 16,000 on the irrigated area. In 1934 the rice crop alone was sufficient to supply the needs of the Commonwealth. Fruit and cattle-fodder also flourish

Several of the dams planned by the Tennessee Valley Authority are well on the way to completion. Norris Dam is expected to be complete in 1936, at a cost of almost £7,000,000. It is built of concrete and is situated on the Clinch river, eighty miles above the point where that tributary joins the Tennessee. It has a crest 1,570 feet in length. Yellow silt is Norris Dam's chief enemy, for the cutting down of forests bordering the Tennessee has loosened the soil. Special measures have to be taken to prevent the dam being silted up and, as a precaution, forests are being planted round the new lakes in order to bind the soil. Wheeler and Pickwick Dams, both part of the Tennessee scheme, are nearing completion, while preliminary surveys for three others are under way.

The great deserts stretching throughout the central basin of Australia are too far from any water supply to make them worth while irrigating. The rainfall is negligible and not a single river flows through the barren stretches. On the edges of the desert, however, where grass and saltbush can eke out an existence and water can be brought from not-too-distant rivers, irrigation projects have been put into practice. But the object of such schemes has usually been to develop poor grasslands which have not been previously occupied.

The best-known undertaking of the kind is the Riverina Irrigation scheme on the Murrumbidgee River, New South Wales. The headwork is the Burrinjuck—popularly "Barren Jack"—Dam, which can store up to 960,000,000 tons of water. It is 240 feet high and 784 feet along its crest, and is built on a quarter-circle curve after the design of the Roosevelt Dam in the United States. This shape has the properties of an arch and gives more resistance against the water pressure than the straight-line dam. The masonry is crushed sandstone in cement mortar, with plenty of large granite "plums" to strengthen it.

Settlement of new inhabitants began in 1912, long before the dam was complete, and now, where formerly there was only poor grazing for sheep, are rich fruit orchards, fields of corn and extensive piggeries. Peaches, apricots, apples and grapes thrive excellently on the well-watered plain.

A larger dam—the Hume Reservoir—begun in 1919 was completed in October, 1934, as part of the New South Wales Riverina scheme. It is situated below the junction of the Mitta Mitta and Murray rivers. Two weirs and locks on the Murrumbidgee, one weir at Yarrawonga, and barrages near the river mouth to prevent silting, are in the course of construction to complete the scheme. Hume Reservoir's capacity is twice that of Burrinjuck and it will probably be used to supply electric power later.

The Dawson Valley scheme in Queensland, now approaching completion, comprises a 140-feet dam at Nathan's Gorge. It will impound some 3,100,000,000 tons of water, which will be used to irrigate a quarter of a million acres of dry grassland.

CHAPTER XXIII

TOWERING FOREST AND IMPENETRABLE JUNGLE

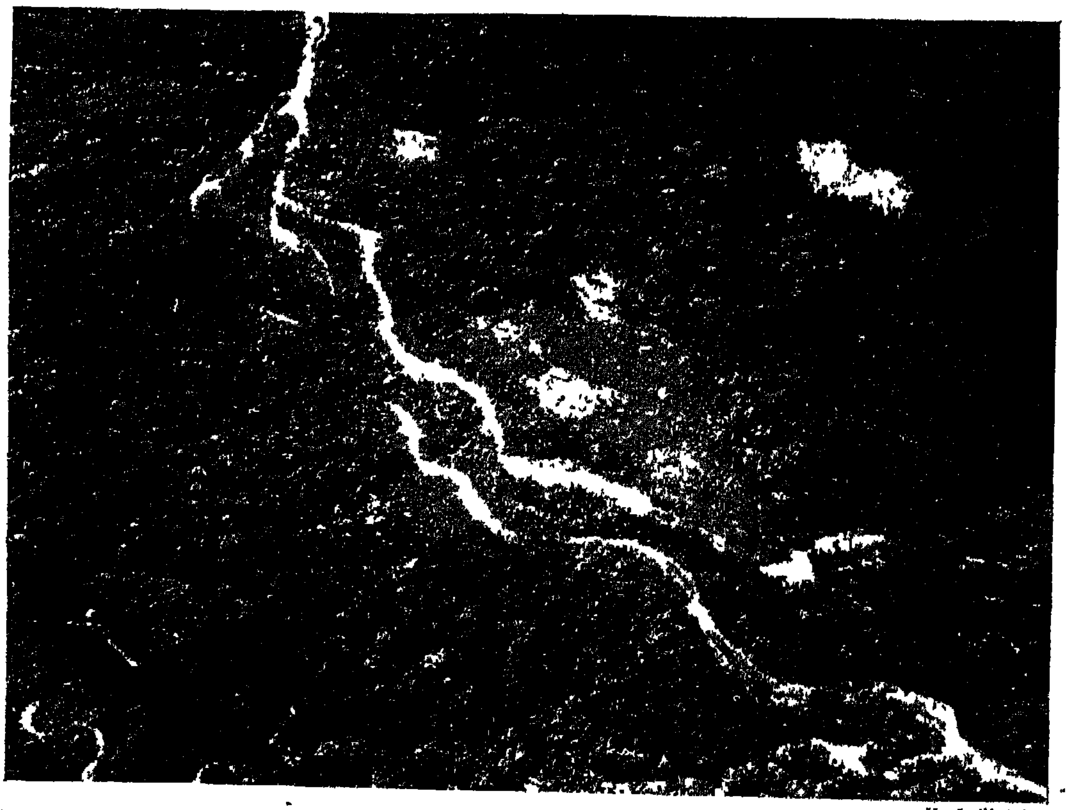
THE Amazon, in some respects the mightiest of all the great rivers of the world, rolls its tremendous waters for 4,000 miles across the broadest part of South America, all but linking ocean with ocean. We have written about this great river itself on another page, and here we shall concern ourselves chiefly with the remarkable country that constitutes the enormous basin drained by the Amazon and its innumerable tributaries. Here is to be found the largest area of virgin forest, much of it impenetrably dense and quite unexplored, on the face of the globe. Upon this dark jungle the vertical rays of the sun beat down mercilessly throughout the long tropical day, as though upon the roof of a gigantic hothouse; yet, so thick is the screen of branches that only a fraction of the heat of the sun, and still less of its light, filters into the dim, chaotic wilderness below.

The heat is stifling; a faint mouldy smell of decaying vegetation fills the motionless air; the soft, yielding earth, formed of the undisturbed, accumulated leaf-mould of many thousands of years, is hidden beneath a rich green carpet of ferns and enormous mosses, from which rise the lofty pillars of the forest trees and an indescribable tangle of undergrowth and creeping plants. Now and then, the narrow track is blocked by a prostrate tree trunk, felled by one of the short, sudden and furious storms that sweep the Amazon. Entirely cloaked in vegetation, it is fast

crumbling into decay, while other great trunks growing so close together that they have not had room to fall full length, lie rigidly in the arms of their fellows in an endless variety of attitudes.

Only rarely are several trees of the same kind found together in the Amazon jungles; the forests of single species, such as the pine woods of the north, are here unknown, so that out of the many scores of trees contained in a large area of jungle, only a few may be of similar kinds; and this lends the scene an inexhaustible diversity. From the roof of the forest, a hundred feet or more above the earth, hang the long, trailing stems of the creepers, dangling in enormous loops and coils among the branches which, like ropes, they link together into a single living mass of green; twining like snakes round the tree trunks or round each other, or hoisting themselves aloft by means of the long curved spines on their leaves and stem. Many of the lianas that hang from the tree-tops are unattached to the earth; they are the aerial roots of parasites which grow upon the boughs at a dizzy height above, and draw their sustenance from the sap of their host; and in their turn they are exploited by convolvuli and other creepers with gorgeous blooms, which twine around them, under the influence of the all-pervading urge to reach the roof of the forest.

The boundless region that lies among the tree-tops has a life of its own that has little connection with that which teems on the earth below; it is, as it were, another world, of which the denizens are chiefly birds and monkeys as well as insects of every possible kind. Most of the Amazonian monkeys are entirely arboreal in their habits, and seldom, if ever, descend to earth, and the great majority of them are very timid and inoffensive little creatures. They travel together through the forest roof in troops of varying size, feeding as they go on fruits and nuts which they pluck from the branches, and swinging themselves nimbly from tree to tree by means of their long, thin arms and strongly prehensile tails—all ceaselessly twittering and screaming the while. The



H. J. Shepstone

Dense forest of the Amazon basin from the air. One of the great river's many tributaries is seen twisting its course through the jungle and in the centre of the photograph is a clearing with a native settlement

H J Shepstone

Though huge tracts of the Amazon forests remain unexplored, in the areas adjacent to towns and villages civilization has begun its work of progress and has thrust its way through the barrier of trees and undergrowth to make roads

spider monkeys, graceful and slender, are coveted by the Brazilians as pets, but other species are just as eagerly eaten for food.

There are monkeys with faces of flaming scarlet, and others again that resemble owls, with yellow staring eyes. There are dainty little marmosets, measuring but seven inches or so in length of body, and there are great, black howlers that make the night hideous with their booming roar.

Occasionally a heavy, cumbrous sloth, bound upon some obscure errand, proceeds cautiously from bough to bough, hanging upside down by his hooked claws. Carefully he tests each bough before entrusting his weight to it; and his shaggy coat, infested with grey-green parasitic algæ, so exactly matches the dull tones of the tree-tops that it constitutes a most perfect disguise.

The bird life of the Amazon jungle is very rich and varied, ranging from the tiny humming-bird, gleaming like a rare jewel in purple, gold or emerald-green, and flitting from flower to flower through the patches of sunlight with inconceivable velocity, to the loud-voiced, yelping toucan, with its enormous, grotesque beak and gaudy feathers. There is the drably clothed umbrella bird, which has a perfect little sunshade of feathers on the top of his head, which he can erect at will while uttering his loud, piping call, like the long-drawn notes of a fife. There are elegant scarlet and black tanagers, and jacamars, kingfishers and trogons, whose brilliant feathers gleam with metallic splendour; while high among the branches, looking like sleepy bats, hang the strange, pendulous nests of the red and yellow orioles. Herons—both white and blue—long-legged storks, crimson-feathered ibises strut about among the swamps and sedges; while overhead, high above the canopy of the forest, fly enormous flocks of pigeons or companies of gaily feathered parrots, proceeding in regular order, two by two. In the Amazon valley is found also one of the finest and rarest of all the parrot tribe, the great hyacinthine macaw—three feet long, of soft, deep, exquisite blue, with a great hooked beak of enormous power. And on the Upper Amazon can be heard the slow, mellow strains of the organ bird, the finest songster of the South American forests, whose clear, fluty and deliberate notes delude the traveller into imagining that he is listening to the

commencement of an air on a musical instrument.

The insect life of the humid Amazon jungle defies all description. Beetles, ants, spiders, moths and butterflies swarm in the air, the tree-tops, the undergrowth, and the habitations of men. In the neighbourhood of a small settlement on the Upper Amazon, H. W. Bates, the naturalist, found no fewer than seven thousand species of insects. There is a moth that wraps its chrysalis in a silken net and suspends it by a long thread from the tip of a leaf. There are leaf insects that can scarcely be distinguished from green or faded leaves, and moss insects that look like sprigs of moss or lichen. In the branches, monstrous hairy spiders, six or seven inches in length, lie in wait for birds, which are entangled in their stout, sticky webs and then devoured. So large and substantial are some of the Amazon spiders that native children may now and then be seen leading one about with a string tied round its waist, for all the world like a pet dog.

Giant Spiders and Glorious Butterflies

Immense numbers of mosquitoes and venomously stinging flies, so numerous as to resemble thin clouds of smoke, make the life of the unprotected traveller a torment, while the terrible red fire-ants, whose sting is like the pain of a red-hot needle, take possession of whole villages and drive out the wretched inhabitants to seek fresh homes. But the beauty of the Amazon butterflies does much to compensate for the evil habits of other insects. Their number is enormous: within an hour's walk of Pará, H. W. Bates found 700 species, more than twice as many as are found in the whole of Europe. The majority of them are delicately lovely, their wings shimmering with a myriad tints. Some of them are giants, measuring nine inches across the extended wings; others are transparent as crystal and delicately veined and spotted, while the resplendent butterfly of metallic blue, from whose pinions the well-known jewellery is made, is visible a quarter of a mile away as it dances about gaily in the sunlight, high above the forest paths.

Comparatively few large animals haunt the jungles of the Amazon. The curious, timid tapir wanders about at night, browsing on leaves and fruit. Herds of wild hogs force their way through the undergrowth; the armadillo and the ant-eater pursue their slow and solitary route. All these animals are hunted and eaten by the Indians. The stealthy puma, spotted all over or else quite black, and the lordly jaguar, king of the South American wild, stalk softly along the jungle paths on the track of the creature that is to provide their supper.

Reptiles are particularly plentiful. Huge anacondas lurk near the pools and streams, waiting to seize the animals that come down to drink. Boa constrictors, "as thick as a man's thigh" (which seems to be the conventional standard for measuring snakes), are common and, being considered quite harmless, are sometimes kept as pets. Of smaller snakes there are numerous species, including some of the most deadly in existence. Lizards of exotic colour and curious form scamper everywhere over the dead leaves, or lie motionless along the branches of the trees. The rivers and their banks swarm with huge turtles, three feet or so in length, which together with their eggs have for many centuries formed a main article of diet to the Indians, though their numbers show little sign of diminution. Most repulsive and most dreaded of all the inhabitants of tropical America, the cunning, cowardly alligators float half-submerged like black and decaying logs, or dragging their fifteen feet of armour-plated muscle on to a sand spit, bask for hours in the sun, waiting perhaps for some heedless creature to wander within range of their heavy tail, only to be knocked down by a lightning blow and dragged into the dark water.

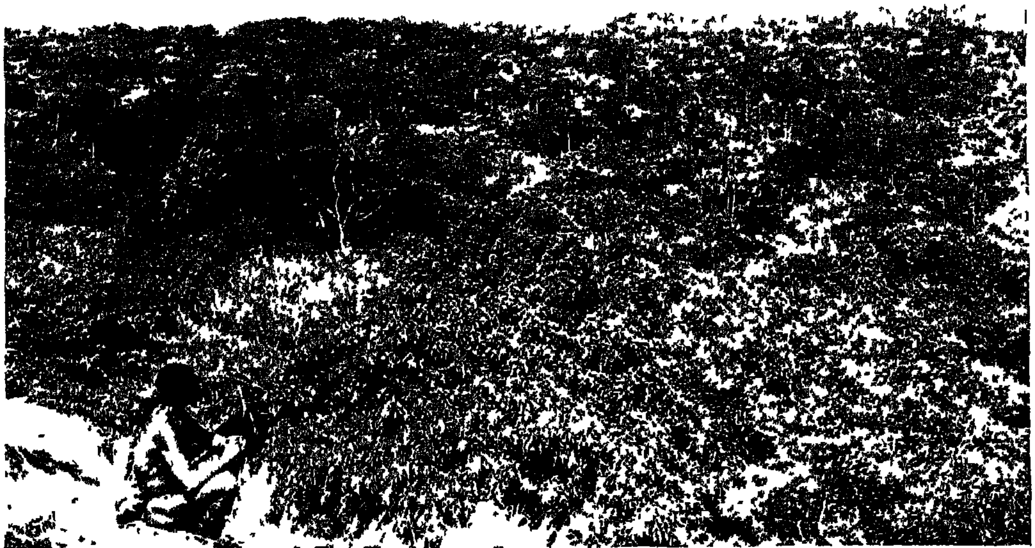
Awe and Terror of a Tropical Storm

A tropical storm breaking over this great jungle is an awful and unforgettable spectacle. The dry season comes to an end about the beginning of February, and at this time sudden furious squalls are liable to occur without the slightest warning. The forest gives voice to its agony in a murmuring roar, above which is heard the terrific crash of collapsing trees, which often bring down others in their fall, inseparably bound to them by the rope-like lianas. The cries of terrified animals and birds are united in a noisy protest against the tempest; while the ceaseless roar of thunder and the clatter of the tropical rain on the tree-tops fulfil the perfect conception of chaos, intensified by the immense and lurid flashes of lightning which scintillate over jungle and river. Yet scarcely an hour later all may be calm again, the dark forest appearing serene and unmoved beneath the moon.

Yet even during the brightest, the most prosaic hours of the day, the voice of the forest has a note of foreboding and mystery,

a murmur arising from the immense drama of life, of alternate joy and tragedy, that is being enacted within its depths. On this subject let us listen to Mr. Bates, who knew the Amazon jungle as few Europeans have ever done.

"We often read, in books of travels, of the silence and gloom of the Brazilian forests. They are realities, and the impression deepens on a longer acquaintance. The few sounds of birds are of that pensive or mysterious character which intensifies the feeling of solitude rather than imparts a sense of life and cheerfulness. Sometimes, in the midst of the stillness, a sudden yell or scream will startle one; this comes from some defenceless fruit-eating animal, which is pounced upon by a tiger-cat or stealthy boa constrictor. Morning and evening the howling monkeys make a most fearful and harrowing noise, under which it is difficult to keep up one's buoyancy of spirit. The feeling of inhospitable wildness which the forest is calculated to inspire, is increased tenfold under this fearful uproar. Often, even in the still hours of midday, a sudden crash will be heard resounding afar through the wilderness, as some great bough or entire tree falls to the ground. There are, besides, many sounds which it is impossible to account for. I found the natives generally as much at a loss in this respect as myself. Sometimes a sound is heard like the clang of an iron bar against a hard, hollow tree, or a piercing cry rends the air; these are not repeated, and the succeeding silence tends to heighten the unpleasant impression which they make on the mind. With the native it is always the Curupira, the wild man or spirit of the forest, which produces all noises they are unable to explain."



Courtesy of the "African World"

Stretching away for miles and miles to the mountains on the far horizon—a characteristic panorama of the vast bush of Equatorial Africa

We will take our last view of the forests of the Amazon as night is falling. As the glowing sun sinks down behind the dark forest, troupes of hoarsely screaming parrots and macaws fly over to their resting-places. Their passing is the signal for an evening chorus from the forest; the mournful screaming of howling monkeys, the shrill whistle of locusts and cicadas, the hooting of tree-frogs, the sinister hum of millions of mosquitoes, blend with countless other noises from near and far into a single, unforgettable nocturne. As darkness closes, the fireflies begin to flit

about the trees, while enormous moths and long-horned beetles fly heavily through the air. Great dark-winged bats—leaf-nosed fruit bats, hideous though harmless, and blood-sucking vampires—issue from the forest in squadrons, and silently flap their way in wide circles over river-bank and swamp.

Wherever there is water, the voices of the frogs are raised in a regular, monotonous concert. "There are three kinds," says Alfred Russel Wallace ("Travels on the Amazon"), "which can frequently be all heard at once. One of these makes a noise something like what one would expect a frog to make, namely, a dismal croak, but the sounds uttered by the others were like no animal noise that I have ever heard before. A distant railway-train approaching and a blacksmith hammering on his anvil, are what they exactly resemble. They are such true imitations, that when lying half-dozing in the canoe I have often fancied myself at home, hearing the familiar sounds of the approaching mail-train, and the hammering of the boiler-makers at the ironworks."

As the evening lengthens, all louder noises, one by one, are stilled and only the incessant monody of the frogs and insects, the melancholy cry of a nightjar or the terrified scream of a distressed animal in the forest, break the silence of the tropical night.

Mysteries of the Congo

In the remotest parts of the Belgian Congo, lying between the headwaters of Africa's two most mighty rivers, is the great Congo forest, whose 25,000 square miles of dark, reeking jungle are still, as they have been since time immemorial, the repository of the inmost mysteries and secrets of a continent. The internal fastnesses of the Congo forest have been seldom penetrated by white men. The undergrowth is so excessively rank and dense that off the beaten track every yard of the way would have to be cut with an axe. Fortunately, there are paths through the jungle, which, though narrow, are kept open perpetually by generations of animals nightly making their way to the water-holes.

Giant trees, roped together with a tangle of lianas, rise for perhaps 200 feet or more on either hand, and their spreading branches form so vast and thick a canopy that the sun, burning with tropical ardour outside, can only succeed in sending a thin pencil of light here and there into the gloom of the forest. During the daytime, twilight for ever reigns; the air is suffocatingly hot and heavy and humid with the enormous radiation of moisture from the living forest. Stagnant water stands about in pools which exhale a noisome smell when disturbed, and over which hang clouds of mosquitoes and venomous flies. Though there is a general similarity about all tropical forests, the jungle of the Congo is less diversified, more awful and gloomy, than that of the Amazon. The plumage of the birds is less brilliant, the general aspect of the vegetation more sombre, and there is everything to warn the traveller that this is a land of peril, not of charm. Enormous pythons lurk by the water-holes; the lion, leopard, hyena and jackal roam the forest paths; elephants crash their way clumsily through the undergrowth, and crafty, somnolent crocodiles swarm in the black, oily mud of the sluggish creeks and streams that eventually feed the Congo.

The Central African forests hold an almost inexhaustible reserve of valuable trees—mahogany, ebony, African teak, camwood (which yields a red dye), and the silk-cotton tree, with its enormous root-buttresses that may project as much as twenty feet. Gigantic tree-ferns with twelve-foot fronds mingle their foliage above the forest paths, roofing them in like a tunnel; while monstrous mosses and lichens grow to luxuriance in the dim light. But of all the myriad plants of the forest the most valuable to man are the tough *Landolphia* vines that hang like draperies over the trees, and yield, on tapping, a superior quality of rubber.

The tree-tops are the undisputed realm of a host of monkeys, including the chimpanzee, whose dreary cries can often be heard from a great distance. Deep in the forest the formidable gorilla is to be found. These great apes wander about in families, occasionally leaving the shelter of the forest to raid the outlying plantations. As night approaches, they construct rude beds for themselves by breaking down the undergrowth into a heap, upon which they sleep in a sitting posture. Travellers in the Belgian Congo have related how these most man-like apes post sentinels in the branches of trees when they are feeding, to give warning of the approach of danger; this tiresome duty is generally entrusted, for some reason, to a young female, but below her, just in case she should allow her attention to wander, is said to be stationed an old male, who summarily recalls her to her senses by reaching up his long arm and administering a sharp pinch.

Towards the eastern boundary of the Congo forest, between Lakes Albert and Albert

Courtesy of the Southern Rhodesian Government

Luxuriant tropical vegetation of exceptional size and often of great beauty is typical of the African forests. A grove of graceful palms near Victoria Falls, Rhodesia

Edward, the rare okapi has its home, and here it was discovered by Sir Harry Johnston in 1900. This strange animal is related to the giraffes, though it has a much shorter neck, and its legs and hindquarters are protectively barred with black and white, so as to render it almost indistinguishable among the tangled vegetation of the dark forest, where nothing can be discerned clearly at a greater distance than twenty yards. The whole of the basin of the Congo is to-day inhabited chiefly by various negro tribes of Bantu stock, but the depths of the great forest still form the last stronghold of the pygmy races, who are believed to have peopled at one time the whole of Central Africa. The tiny stature of these diminutive men and women is the legacy of many thousands of years passed in the close confinement of the forest, where the struggle for existence may produce trees and plants of enormous height, but succeeds only in dwarfing the human frame. So the pygmies have become very well fitted by nature for darting nimbly through the dense undergrowth and climbing aloft amid the intersecting branches and tangled lianas, for grasping which they use both fingers and toes. They are mighty hunters, too, overwhelming even the buffalo and the lordly elephant with showers of their tiny arrows, which are tipped with a deadly poison made from decaying ants — for the pygmies are acknowledged masters of all that relates to poisons and their antidotes. In their diet, they are among the most unsqueamish of mortals, and though relishing fruit, honey, mushrooms and the flesh of birds and beasts, they will just as readily eat caterpillars, grubs and white ants.

Photo. A. W. Exell

Fostered by the intense heat, flowers and shrubs frequently attain enormous dimensions in the primeval forests of Equatorial Africa. Here is a giant Begonia (*Begonia baccata*) with a height of 4-10 ft., leaves up to 2 ft. across and handsome heads of white flowers growing on an island in the Gulf of Guinea

Life in the forest, where the prevailing law is "kill or be killed," has sharpened the wits of these little people, who on the whole rank higher in intelligence, for all their stunted growth, than the negroes of the open bush. Pygmies have on several occasions been taken sightseeing to Europe, and have shown a lively interest in all the strange things they have seen. A number of them were brought to England from the forest of the Ituri River, an easterly tributary of the Congo, in 1906, and aroused universal wonderment. Of these pygmies the smallest was barely more than 3½ feet in height, though the average stature of African pygmies as a whole is more than 4 feet; they can easily walk erect under the outstretched arm of a man of ordinary height.

But the jungle has other and more sinister inhabitants than the entertaining pygmies. Many of the tribes of the Congo have been cannibals since time immemorial, and it is only the dread of the white man's law that

holds their ghastly appetite in reasonable check. In the jungle fastnesses, where there is no higher authority than man's own passions, savage tribal feuds are carried on and grim magical rites, trials by ordeal, and human sacrifices of indescribable horror have a regular—though perhaps surreptitious—part in everyday life. In the Congo jungle fear has ever reigned triumphant—fear of the native's tribal foes, of his neighbour, of famine and wild beasts, of the Arab slaver, of the spells of the medicine man, of sleeping sickness. And yet the time may not be very remote when even this darkest corner of the Dark Continent is brought within the pale of civilization. Already highways have been opened through the jungle, railways are increasing gradually mile by mile, while one of the most daring air-routes in the whole of Africa—between Leopoldville, on the Lower Congo, and Stanleyville, above the Stanley Falls, a distance of over 1,000 miles—traverses an enormous stretch of the primeval Congo forest. One is tempted to wonder what would have been the thoughts of those who did the pioneer work in the unlocking of this part of Central Africa—Livingstone, H. M. Stanley, George Grenfell, to name some of the most prominent—concerning this latest stage of the great adventure.

Teak Forests of the Indies

A study of the occasions on which plants have brought about major changes in the fate of nations would be illuminating. The high price of pepper in the Middle Ages, for example, was one of the prime causes that induced the Portuguese to seek a maritime route to India round the Cape; while the cultivation of the cotton plant by negro slaves in America led to the fratricidal war between North and South. Similarly, it was in great part owing to the valuable reserves of teak in the forests of Burma that this vast territory was annexed to the British Crown after the conclusion of the third Burmese War of 1885. Iron ships were rapidly replacing those built of wood, and it was found that whenever iron was combined with the traditional oak, as in the plating of men-of-war of the period, the metal was rapidly corroded by the acid contained in the oak; while when teak was used instead of oak, its essential oil had, on the contrary, a preservative effect upon the iron. So, though sturdy oak has had to relinquish the proud place on the sea which it held for so many centuries, teak is still in great demand in shipbuilding, being used for rails, doors, deck-planking, and almost everywhere, in fact, where metal is not essential. Teak is tough, elastic and not much heavier than oak, and when used for ornamental effect it takes a beautiful natural polish of a golden-brown hue. When properly seasoned, it does not readily warp or split, and the fresh-cut wood can be worked with ease, though after being seasoned for a fair length of time it becomes intensely hard.

An Indispensable Timber

But the foremost virtue of teak is its great durability; it rises superior to all changes of temperature and climate, decay, the passage of time, and the assaults of white ants, which, sooner or later, manage to devour almost every kind of timber. In India, original beams of teak, still sound and strong, have been found in buildings known to be well over 1,000 years old, and an antiquity of more than twice this span has been estimated for pieces of teak found in cave temples of western India. Throughout the East teak is indispensable; it is used for making houses, bridges, furniture and railway carriages, while its power of withstanding immersion for prolonged periods renders it eminently suitable for boats, piles and all other kinds of under-water work. Even the leaves of the tree are of service; of enormous length—one, two or even three feet—and very tough, they are used by the natives as plates or for thatching the roofs of their houses, while a red dye can also be extracted from them.

Let us visit this valuable tree in its native forests, of which the largest, by far and away, are to be found in Burma. The principal reserves lie in the basins of the Irrawaddy and the Salween, and in the coastal provinces of Pegu and Tenasserim, while the Shan States and western Siam also contribute a large share. In all these districts there are forests of enormous extent, which during the rainy season stand out from a great distance as a billowy white mass, for at this time the clusters of small, snowy flowers break into bloom above the green leaves. Teak trees, however, do not grow alone over a large area, as do the conifers of northern lands, but mingle their tall, straight stems with those of other trees of many different kinds—india-rubber trees, padauk, the immensely hard ironwood, cutch, which yields an important dye, and countless others; while dense clumps of bamboo raise their feathered spikes in between the trunks of their larger brethren.

Teak is not an evergreen, and during the

dry season its branches, together with those of many of its companion trees, are bare of leaves, which gives the forest a dead and dreary appearance. This is the season of danger, when forest fires are prevalent, which, sweeping irresistibly through the tinder-dry undergrowth, destroy many thousands of young trees, or at the best retard their growth and spoil their timber with cracks and blemishes.

The Burma forests are of the usual tropical density. Creepers, many of them covered with brilliant flowers, hang in a tangle from the trees, and orchids, ferns, mosses and epiphytes grow in great luxuriance, often forming a scene of wonderful beauty, such as is typical of the jungles of Asia. The scent of flowering trees and bushes hangs heavily on the air, while exquisite butterflies and no less exquisite birds—including gorgeous peacocks and pheasants of extraordinary beauty—make a veritable paradise of the jungle glades. The typical animals of India roam through these mighty forests—the elephant, buffalo, bison, rhinoceros, sun-bear, wild hog, tapir, deer of many kinds; velvet-footed tigers and leopards slink along the jungle paths, packs of hideous wild dogs silently and remorselessly hunt down their quarry, while the python, cobra and deadly hamadryad lie in wait to seize the unwary.

In former days the natives of Burma used their magnificent teak forests—the finest in the whole of Asia—in a very wasteful and destructive manner. Besides cutting the timber on a large scale for charcoal-burning, they had long been in the habit of burning whole tracts of virgin forest to the ground to provide room for their crops; and after a few years, when the soil was exhausted, a fresh stand of timber would suffer the same fate. In 1855, however, the Indian Government took the matter in hand, and began to reserve large areas of forest-land, carefully regulating the cutting of timber and establishing plantations so as to maintain the supply. At the present day there are nearly 30,000 square miles of reserved forest-land in Burma, mainly supplying teak, which ranks as the second most important product of the province. The reserves are leased to timber companies, who fell the trees under government supervision, the annual out-turn of teak usually being considerably more than

Courtesy of Imperial Airways

In the magnificent teak forests of Burma and Siam, where these valuable trees grow to a height of 100-150 feet, trained elephants are used to haul the logs to the river or stream down which they are floated to the timber-yards. Here are two of the powerful beasts at work in a forest near Bangkok

Courtesy of the Australian National Travel Association

The forest-lands of Australia are principally noted for their fine timber, but on the northern coasts of the continent is to be found sub-tropical jungle which rivals Africa in the luxuriance of its vegetation

a quarter of a million tons. Before felling, the trees are killed by being girdled at the base, and they are then left standing for two or three years to season. The felled logs are then floated downstream, one by one, over the numerous rapids. On the Salween, which is the greatest timber thoroughfare in Burma, the logs are caught by a cable stretched across the river, seventy miles above Moulmein, where they are gathered into rafts before proceeding to this great timber port. The haulage of the heavy logs is done mainly by trained elephants, and in the great timber-yards of Rangoon and Moulmein it is instructive to see with what skill and precision they go about the work, two to a log, grasping the heavy baulks between their trunks and tusks and stacking them neatly in piles, at a few words of command from their drivers.

Jarrah and Karri Forests

The rank, steaming jungles of Asia, Africa and tropical America have scarcely a parallel in Australia (except, perhaps, in the sub-tropical vegetation of the north and eastern coast), but the southern continent has a vast forest-land and bush of its own that are quite distinctive The prevailing aspect of the Australian bush is not attractive; mile after mile, with scarcely a break, the parched earth is covered with a sombre and dusty scrub of dwarf eucalyptus, or with monotonous acacias, or slender "grass trees," or dreary heath, while acres of burnt grassland and the blackened stumps of trees do little to raise the spirits of the traveller. But the scenery of the great gum forests is very different. These noble trees—which are the commonest forest trees in Australia, and number several hundreds of different species —grow to a portentous size, being frequently over 200 feet in height. Their leaves are large and leathery and have their edges turned towards the sun, a fact which makes the forests of Australia much less dark and shady than those of other lands The gums are all classed as hardwoods, and they yield timber which is tough, durable and resilient under all conditions. Many species, moreover, yield the gum or resin known as "kino," contained in the bark, while from

Courtesy of the Australian National Travel Association

The Karri (*Eucalyptus diversicolor*)—one of the Australian gum trees—is highly valued for the exceptional durability of its timber. It is most prolific in the south-western districts of Western Australia, where the lofty trunks stand in close ranks for mile upon mile

the leaves of others the familiar eucalyptus oil is distilled. Perhaps the most valuable tree of all the gums is the jarrah, with the karri making a good second. These timbers are alike hard, heavy and close-grained, but their chief virtue resides in their intense resistance to damp, fire and the attacks of white ants and boring sea-worms, so that they are especially in demand for foundations, submarine piles, railway sleepers, paving blocks, etc. A valuable tanning extract is derived from the bark of karri, and both these gums provide fine timber for furniture.

Jarrah and karri both occur in the timber stands throughout Australia, but the state of Western Australia is pre-eminent as the home of these fine trees. Here there are estimated to about 14,000 square miles of jarrah, as well as an immense reserve of karri; the most densely timbered area—and perhaps the most valuable forest region in the entire continent—being the south-west corner of Western Australia, enclosed roughly by the railway line from Albany to Perth. Here, solidly massed in dense stands on the mountain slopes and in the valleys, the gums attain their most impressive dimensions, commonly displaying a height of 300 feet, with a girth of thirty feet or more; while giant karris may measure no less than 150 feet as far as the point from which the lowest branches spring. Between these mighty trunks that rise as straight and parallel-sided as cathedral pillars, there have intruded deep banks of feathery ferns, flowering acacias, Australian honeysuckle, creeping and twining plants without number.

Wallabies, large and small, leap about in the patches of sunlight, bulky wombats wander at night on the fringes of the forest, graceful little phalangers spring adroitly from bough to bough, the curious little striped ant-eater, with its handsome bushy tail and its fifty-two teeth—a record among quadrupeds—roams about in search of ants. The forest echoes with the cries of birds—gay little parakeets, honey-eaters, quails and pigeons, bringing a welcome change from the silence of the scorched and arid plains without. But the most insistent sound in the forest has for long been the resonant ring of the axe and the grating of an army of saws, all busily engaged in turning hundreds of giant gum trees into lumber.

We have no need to go to the other end of the earth to enjoy the wonderful scenery that only a primeval forest can afford. It is true there is very little timbered land left in England—though at one time, it is believed, practically the whole of England was one vast, almost unbroken forest—but in the Scandinavian region, just across the North Sea, some of the grandest forests in the world are to be found. These are chiefly composed

Photo Norman *Courtesy of Norwegian State Railways*

Sombre masses of fir-trees covering the mountain-slopes of the Rendal Valley in Eastern Norway. In this Scandinavian country alone there are over 17,000,000 acres of pine forests

of coniferous trees, yielding soft-wood—by far the most valuable kind of timber, from an all-round point of view, since it yields wood-pulp, paper, cardboard, rayon and other commodities, as well as being used for constructional purposes. Among the conifers in the dark, brooding forests of Norway, Sweden and Finland one tree is predominant —the magnificent Scotch fir (*Pinus sylvestris*), which, as its botanical name signifies, is really to be classed as a pine. Next in importance comes the Norway spruce, which is a true fir, followed by birch, beech, oak, willow and others.

In Norway alone there are over 17,000,000 acres of forests, which extend more than 3,000 feet up the snow-clad mountain slopes, and cover nearly a quarter of the whole country. Dark belts of pines cover mile after mile in central Norway, interrupted only by gleaming lakes and swift-flowing rivers; they run down to meet the waves of the sea, clinging to the edges of the fjords, and northwards they project far beyond the Arctic Circle into the land of the Midnight Sun, only ceasing where the land becomes too bleak and barren to sustain them, and giving place to stunted willows and dwarf birches, drab lichens and reindeer moss.

Sweden has no less than 55,000,000 acres of forests, chiefly pines, from which millions of tons of wood-pulp are manufactured yearly —in fact, nearly a half of the wood-pulp supply of the world is produced by Sweden, where the timber industry has been brought to a high development. But of all the European countries, except Russia, the wealthiest in timber is Finland where, it is estimated, there are more than 62,000,000 acres of forests, supporting a huge industry in timber and timber products, which form the chief export trade of the country. No one who has visited the "Land of a Thousand Lakes" can forget the supreme beauty of the mighty pine forests, the countless clear lakes which they encircle, the green islands mirrored in the calm water, made gay in summer with flowers and the white trunks of the tremulous birch trees, and in winter shrouded heavily in snow. The fresh invigorating scent of the pines is everywhere, and the subdued roar of innumerable cataracts and rapids is perpetual.

Animal Life in the Northern Pine Forests

The great northern pine forests have a wild life that is distinctly their own. The bear, wolf and lynx still make their home here, though driven into fastnesses ever more and more remote by the cutting of the timber. The lordly elk and reindeer roam the lonely forests of the Arctic Circle, and the glutton, Arctic fox and lemming are found on the wooded highlands. Hares are plentiful, and, like the foxes and weasels, they don a habit of white to match the winter snows. Game birds perch up high amid the thicker branches of the pines, secure from prowling eagles; while even the darkest recesses of the less remote woods echo with the songs of birds. But in the lonely forests of the Far North wild life is less exuberant, and for the most part silence reigns; birds are few, and the stealthy tread of a prowling lynx or fox scarcely suffices to rustle the thick carpet of pine-needles that lies everywhere between the great dark trunks, though occasionally a flock of migrating cranes, flying high over the forest, utter their wild, trumpet-like cry.

In mid-summer, when the sun does not set for weeks in these northern latitudes, the unending day is made bright with flowers, while myriads of viciously stinging mosquitoes —the scourge of the Arctic Circle—make merry in the sunlight. But in winter time night exacts a full recompense; for a period of weeks the sun does not rise above the horizon, and even at midday the snow-draped spikes of the pines are barely seen against the drab sky, as through a perpetual twilight.

Spacious Timber Lands of Canada

It is fitting that our tour of the great forests and jungles of the world should terminate in the spacious timber-lands of Canada, the largest and finest in the whole of the British Empire. Nearly one-third of the entire Dominion—or about 1,153,000 square miles—is covered with forests, and the lumber industry and those to which it gives rise, such as the manufacture of pulp and paper, rank only second to agriculture in the economic life of Canada. In 1932, the total stand of timber was estimated at the enormous figure of 266,844,000,000 cubic feet, of which more than four-fifths consists of coniferous, or soft-wood, trees. This huge reserve of timber is located chiefly in a great belt, 300 to 400 miles in width, crossing the north of Canada from Labrador to Alaska.

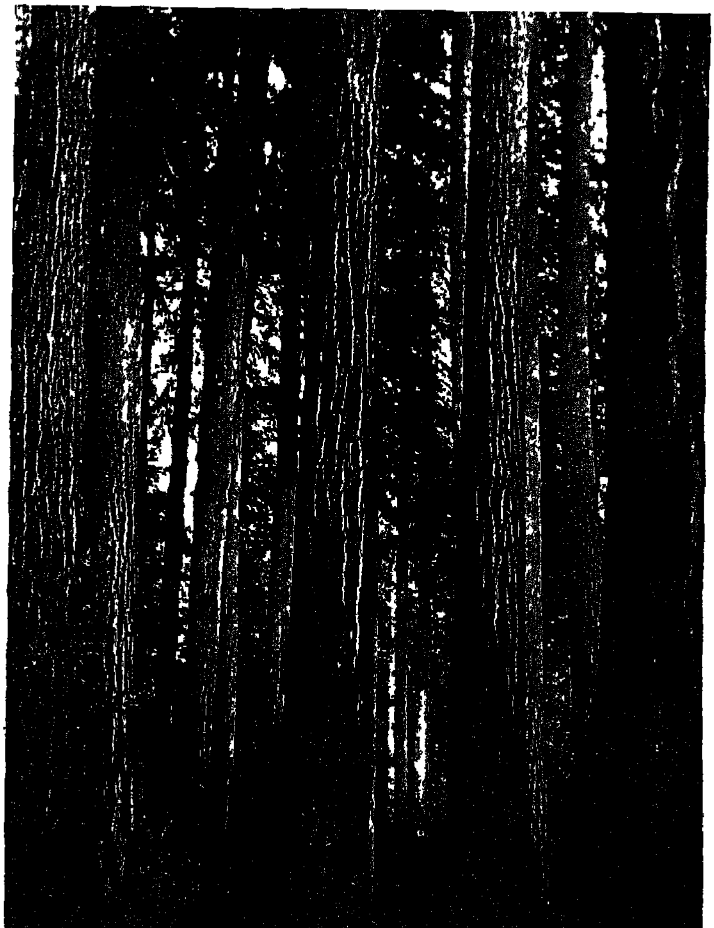
The largest forests—sixty-four per cent. of the whole—are congregated in the eastern provinces, especially in Quebec and Ontario, which have nearly half a million square miles of timber-land between them; however, British Columbia, in the west, holds twenty-four per cent. of the Dominion's forests, and

can boast of having the largest and finest trees of all, especially the lordly Douglas fir, which not infrequently may rise to a height of well over 200 feet, with a perfectly straight and tapering trunk ten feet across at the base. The other principal trees of Canada are the spruce, white pine, hemlock and cedar, and of these the spruce (of which there are several kinds) is the most in demand for making pulp and paper, the leading manufactures of the Dominion.

In the eastern provinces grows the red spruce; the Engellmann spruce and Sitka spruce are chiefly found in British Columbia, where the great Sitka spruce almost rivals the Douglas fir in height; while practically throughout the whole of the timber belt grow the black spruce and white spruce (the most important of all for pulp)—the former forming thick forests in moist and marshy districts, the latter, a smaller tree and the hardiest of all, flourishing even on the barren wilds far within the Arctic Circle, the home of the musk ox and caribou, where few other trees can gain a footing.

With all their majestic beauty, the great Canadian spruce forests are wild and lonely in the extreme, so it is only natural that they should have become one of the last retreats of the larger animals of North America, which are gradually diminishing before the invasion of their hereditary domains by civilization. The lordly moose still crash through the northern woods. The caribou ranges through the greater part of the forest belt, as also does the gaunt grey timber wolf. Black bears still make their home in the most secluded depths of the forest, while in the wooded mountains of the west the terrible grizzly has to be taken into account by hunters and travellers.

Alarmed by the steady depletion of standing timber, the Canadian government has taken timely steps to ensure a perpetual supply by afforestation on a large scale and by strict regulation of the cutting. But more destructive even than the axe and saw are the disastrous forest fires which on an average consume about 230,000,000 cubic feet of timber in a year. In the old days little could be done to prevent these holocausts or to extinguish them when once started, but modern progress has given the Forestry Department many valuable aids. Elevated watch-towers are equipped with telephone and wireless to summon immediate assistance, while aeroplanes—and, in the lake regions, flying-boats—constantly patrol the timber lands, alert for the slightest cloud of smoke that might betoken an outbreak. There is also a large ground staff whose duty it is to keep open the treeless lanes between wooded areas, to extinguish fires, and last but not least, to teach the public, by means of lectures and demonstrations, how best they can safeguard their valuable heritage of forest.



Courtesy of the Canadian Government

Tall, straight trunks packed in close formation—a typical view in the famous fir forests of British Columbia

CHAPTER XXIV

THE WALL BUILDERS

THE age of great wall building belongs to the past. When men began to live together in settled communities they found that their best defence against marauders was an enclosing hedge or fence. In Africa men still plant thorn hedges and erect wooden palisades round their huts. But thorn hedges and timber stockades could be set alight, and the wall made for protection often became a wall of death and destruction to the builders. So earth-banks came in time to take the place of old hedges and fences. Even as late as 50 B.C. an elaborate form of earth and timber enclosure was used by the Germanic tribes to protect their townships. Alternate layers of stones, earth and tree trunks presented a steep face to the assaulting forces. The top was flat and of a moderate width, for on this parapet the defenders could stand and cut down the invaders. It is in Asia Minor and Mesopotamia, however, that the most wonderful examples of fortified city walls have been found.

The Assyrians in 2000 B.C. had long passed the stage of earth-bank fortifications and used stone and rock, bonded with mortar, to build their walls. Even in those distant days of despotic power and unlimited labour, the expense of building a high solid wall, wide enough at the top for defenders to move about on it freely when fighting, would be enormous. So the plan was introduced of building two stone walls with a filling of earth or rubble between them. The outer wall was built higher than the inner, as a protection from stones, arrows and spears. Towers at intervals were added later, and provided refuge for the defenders if the outer wall was successfully scaled.

Nineveh, the capital of Assyria in 2000 B.C., was encircled by such a great wall fifty miles long. It not only enclosed the palaces, temples, merchant-quarters and town-workers' dwellings but provided sufficient space to shelter the whole population of the surrounding countryside. Flocks, herds, household goods—in fact everything except the field army—were protected by the mighty wall, which rose to the amazing height of 120 feet. Its width at the top was thirty feet, forming a road as wide as many modern thoroughfares; and 1,500 towers at regular distances strengthened the fortification.

The *Iliad*, an epic poem of the Greek Homer, tells of the ten-year siege of the walled city of Troy in Asia Minor, probably in the 13th century B.C. Behind their impenetrable city-walls the Trojans stubbornly held out. Virgil in his *Æneid* carries on the story and tells how the Greeks, resorting to a trick, pretended to withdraw their forces but left a great wooden horse filled with soldiers on the plain outside. The Trojans after a long discussion decided to knock down part of their wall to get the great creature into the town; but at night the hidden men crept out to open the city gates, and Troy was taken. Excavations in 1893 exposed part of this massive wall of carefully squared blocks of stone.

Jerusalem, too, is a city famous for its walls. In the 13th century B.C., the Israelites invaded the country now known as Palestine. The Bible story of the fall of Jericho shows how greatly the inhabitants relied on city walls for their protection. Jerusalem was encircled by a stout wall strengthened by towers when it fell into the hands of the Israelites. King Solomon later built, and in part rebuilt, another wall about the city. When the Israelites were subdued by Assyria, about 650 B.C., Hezekiah improved the wall and its defences. But so great was the destruction of the city in 586 B.C., on its capture by Nebuchadrezzar, that it was not until 140 years later that the broken walls were rebuilt, this time by Nehemiah. Then came Greeks, Romans, Saracens and Crusaders and finally Turks, some tearing down, others patiently rebuilding the walls of the holy city of Christendom. The present wall was built in 1517, by Selim I of Turkey.

The Long Walls of Athens

There was another great period of wall-building during the rise of the city-states of ancient Greece. Each city was independent, controlling as colonies the lands lying outside the city walls. Athens, the greatest of these walled states, was a city of note, even in the Bronze Age. Around the Acropolis, a hill naturally suited for the building of a strong citadel, a strong wall of large, rough, unbonded stones was erected.

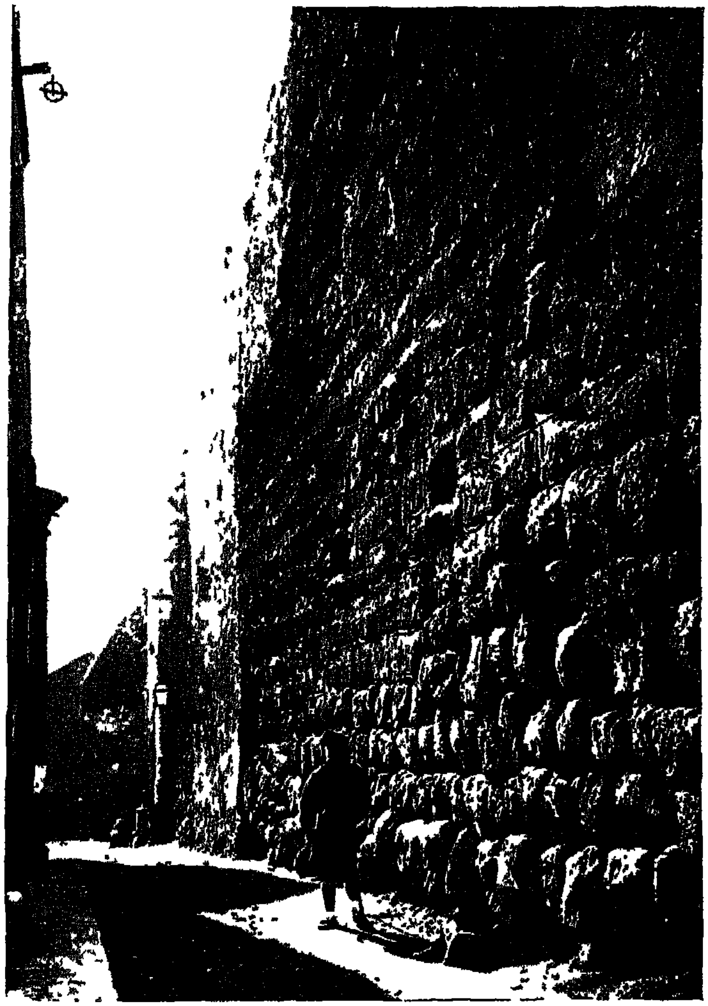
In the 5th century B.C. Athens was devastated by the invading Persian army. Walls and city buildings were left in utter

ruin, but fortunately the rulers rose to the occasion. New city walls, about five miles long, were built under the direction of Themistocles and embraced a larger area than the previous wall-circuit. New districts were enclosed and numerous towers strengthened the fortification.

Themistocles planned, too, a "Long Wall" running from Athens to her port of Piræus. Actually, three walls were built about 450 B.C. The north and middle walls are some four miles long and run almost parallel about 550 feet apart, quite near the present road from Athens to Piræus. The third or Phaleric wall had a separate course much farther to the south, but proved difficult to defend and was abandoned some fifty years later, at the close of the Peloponnesian War. About this time also, the other two long walls were partially destroyed and later fell into decay.

The city walls of Athens itself suffered severely during this long struggle, but were restored and reconstructed some sixty years later. When the Romans ruled in Athens these walls suffered another change. Hadrian then enlarged the wall-circuit to the east, enclosing what is now the Royal Gardens and Constitution Square. The new area was called Hadrianopolis or New Athens. It was a handsome suburb with villas, baths and gardens and its walls were strengthened with rectangular towers. But the greatness of Athens had departed and the city passed successively into the hands of Byzantines, Italians and Turks. Defensive walls were of little avail against the new engines of war, although in 1778 the Turks built a new wall around the city, despoiling many ancient monuments for the building material that these provided.

It was not until the 6th century B C. that the Romans built a stone wall around their city. This, Servian Wall, as it was called, from its builder Servius Tullius, was six miles long and enclosed an area sufficient to house 200,000 inhabitants. Not all the land enclosed was developed at the time, for with the



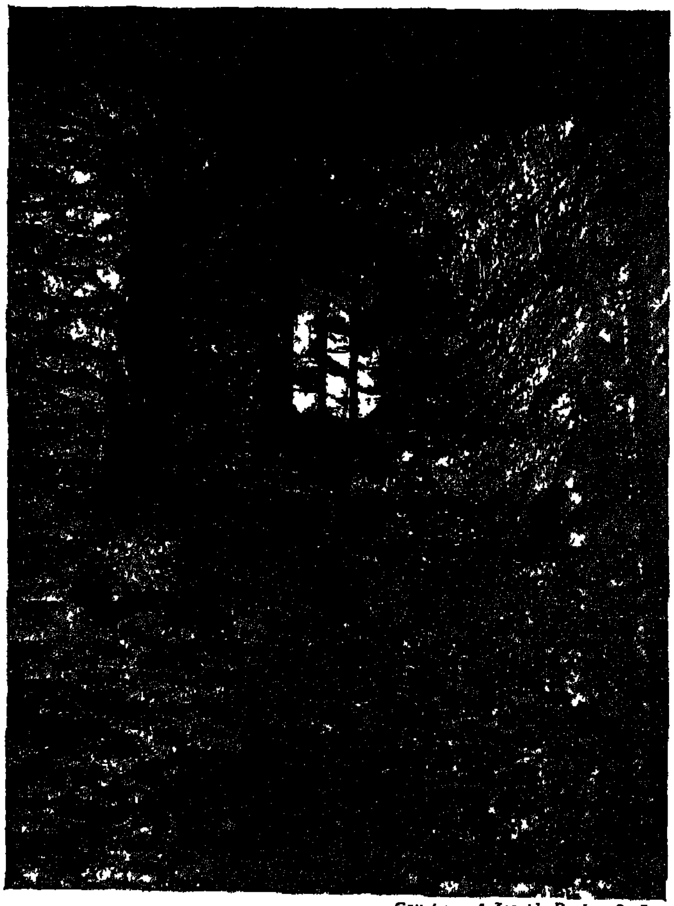
E.N.A.

It was the custom of the Romans to build defensive walls round important towns captured during military campaigns, and remains of these are to be found in many places. At Tarragona, on the Mediterranean coast of Spain, the great Roman walls were erected on a foundation wall of enormous unhewn blocks of a still earlier period. On the inside of the walls, Iberian masons—probably working under the direction of the Scipios—left their marks which are still visible

usual Roman eye to military strength, the wall ran along the natural escarpments. The building was done by the forced labour of the citizens, aided no doubt by that of serfs.

Two centuries later, after a great fire, the wall was rebuilt and strengthened; it was improved also at various later dates. A

Courtesy of the London Museum



Courtesy of Joseph Barber & Co.

A loophole in London Wall which can be seen to-day. It is in a well-preserved section of the wall which forms part of a warehouse close to Tower Hill, where also is a length of the old sentry-walk. From the reconstruction of Roman London (*top*), some idea may be gained of the magnitude of the original wall

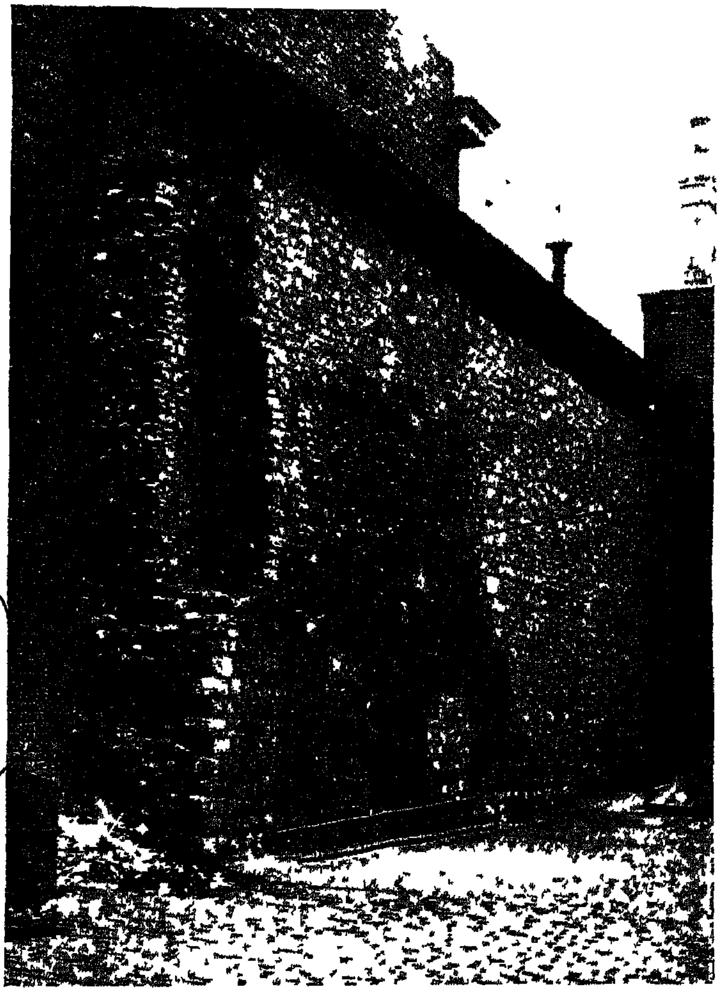
small gate is still to be seen inside the Palazzo Antonielli, and other portions have been uncovered during the course of excavations. On the flatter land to the south, the wall was particularly vulnerable to attack. Excavation has shown that the wall here was about ten feet thick and more than thirty feet high, whilst a moat thirty feet deep and 100 feet wide had been dug in front of it.

Around the principal cities of the many countries they conquered, the Romans erected protecting walls. Lugo, in Spain, has the best preserved Roman walls of their kind—thirty to forty feet high, with eighty - five semi - cylindrical bastions. Since the walls are over twenty feet thick there was room and to spare for two chariots to be driven abreast on the top.

To-day Greater London, the largest city in the world, spreads unprotected into seven English counties. In early days, possibly 4,000 years ago, the inhabitants of the settlement by the marshy Thames built earthworks and wooden stockades to protect themselves both from wandering tribes and from the flood-waters. They occupied their stronghold for 2,000 years.

Then came the Celts from Gaul, and occupied the "Stronghold in the Waters," for that was the meaning of the Celtic name they gave to the settlement—London. But although the Celts traded in tin and bronze, and London became an important centre of this commerce, no attempt to build sturdier walls was made until after the Romans conquered Britain. The need for a strong defensive wall was made clear to the conquerors in the year A.D. 61. The British warrior queen Boadicea, on the withdrawal of the Roman troops by Suetonius, gathered together an army and successfully attacked the city, sacking and utterly destroying it. The inhabitants were massacred and the houses set on fire.

When Boadicea's revolt had been suppressed the Romans commenced to rebuild and fortify the city. An attempt was made to rename it "Augusta," but the outlandish name was never accepted by the Britons, who persisted in calling the city London, or Londinium, the Latinized form. An encircling wall of stone was built, with a ditch beyond. At the base the wall was eight feet thick, being strengthened by a footing of sandstone on the outward side. Like the walls of Nineveh and Rome, it had two well-made outer walls, the core being filled with well-mortared rubble. The facing was made of Kentish ragstone, the nearest available stone of any strength, and bonding tiles were placed at regular intervals. Massive fragments of the wall yet remain, and all show the same masonry structure, indicating that it was built as a single undertaking. The area enclosed within the wall was 324 acres, and the structure was the most ambitious of any built by the Romans in Britain. It compared in magnitude with any such defensive wall in the Roman Empire itself.



Courtesy of the Tower Hill Improvement Council

In Trinity Place, adjacent to Tower Hill, a fine portion of London Wall still stands though there is nothing to indicate its historical interest to the visitor. The Tower Hill Improvement Council are excavating in the immediate neighbourhood in the hope of revealing further traces of the wall

Although some of the wall fragments are hidden under buildings or built into warehouses, yet the course of the wall round the city of London is fairly easy to trace. The names of some of its gates—Newgate, Aldgate, Aldersgate, Bishopsgate, Moorgate, Cripplegate and Ludgate—still survive as street names. Billingsgate was the site of a gate leading to the river. Even as late as the 18th century, everyone had to pass through one of these gates in order to enter the city.

When the Danish invasions began in A.D. 880, King Alfred made London his base; he repaired the walls and built a number of new gates. During the next hundred years

London withstood half a dozen sieges. The longest of these was the last, when the city shut its gates against the newly-elected king Canute, who then attempted to take the rebel city. But his ships were sunk and his army scattered. Only when Edmund Ironside, their chosen king, died in 1016, did the Londoners reluctantly acknowledge Canute.

The largest portion of the Roman wall still in position is enclosed in the structure of a huge warehouse. It is about 120 feet long, eight feet thick and thirty-five feet in height. from the little-known north and were a constant menace to the development of new towns and the progress of Roman civilization.

Agricola set himself the task of making peace more attractive to the Britons than war. He encouraged them to build temples, houses and market places, whilst he and his Roman legionaries took over the military defences of the country. Excellent forts were built at strategic points; in particular a series of forts across the narrowest part of Roman Britain were erected in A.D. 79.

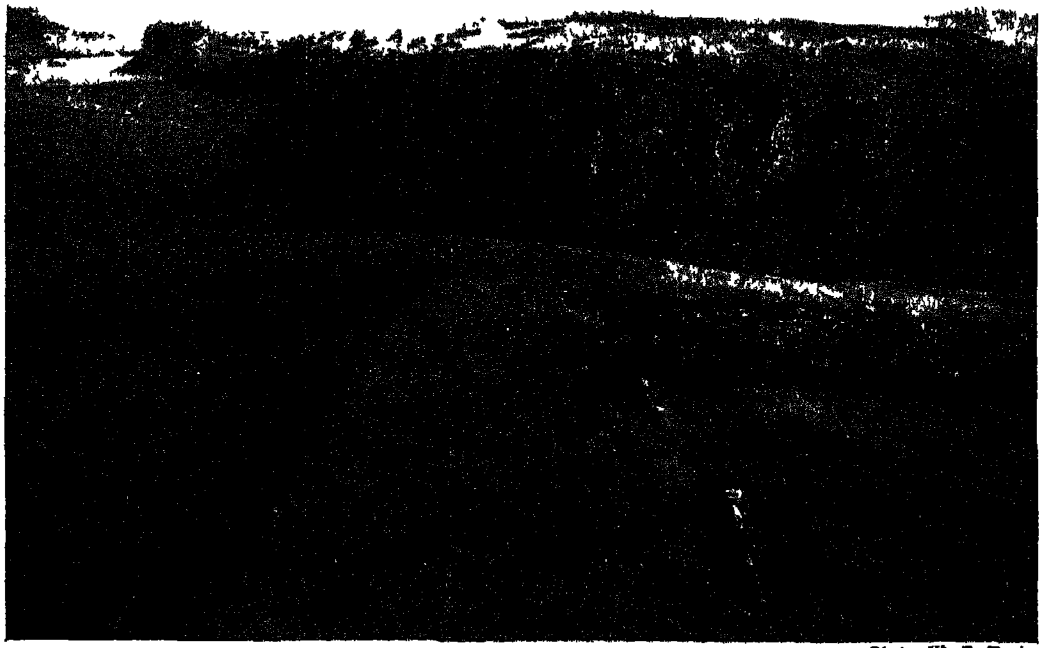


Photo: W. F. Taylor

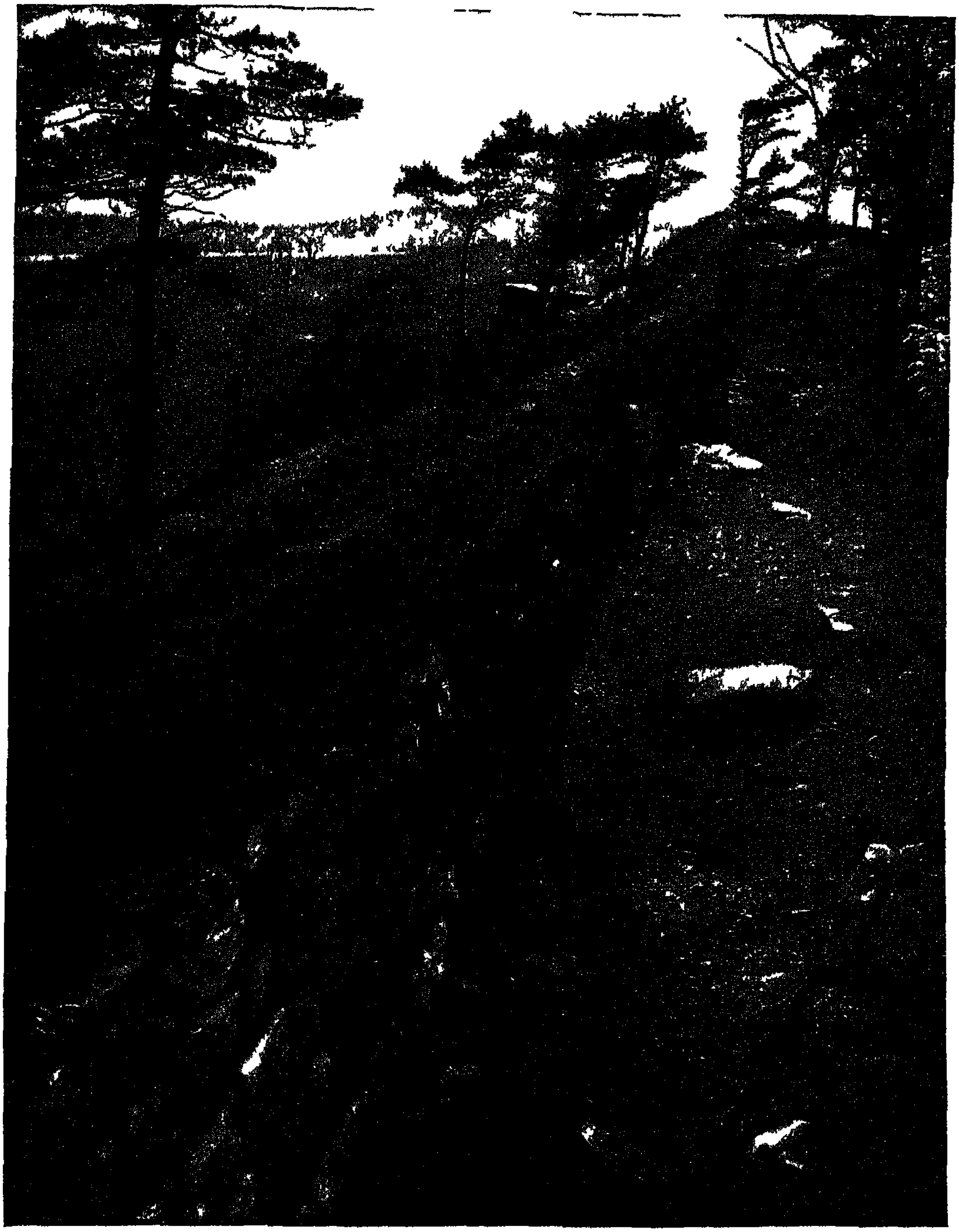
Near Sewingshields, Hadrian's Wall crowns the brink of a natural precipice—the Great Whin Sill of Northern England. Here the wall is from 5-6 ft. high and the drop to the moors below sometimes as much as 200 ft. This photograph was taken looking east towards Crag Lough and Hot Bank

The battlements are still in place and the footway where the sentries used to walk is intact. Making due allowance for sinking, it is probable that the original height was greater than thirty-five feet. Most Roman ruins in London are now found at a depth of twelve to twenty-five feet below present surface levels, so that London Wall may well have been over fifty feet high.

From the first Roman invasion under Julius Cæsar, in 55 B.C., to A.D. 78, when Agricola was appointed governor, the rule of Rome in Britain had not been a peaceful one. Tribes were constantly rebelling and turbulent invaders, the Picts and Scots, sallied

These latter, extending from Carlisle to a spot near the present town of Newcastle, were built to protect the southern country from the constant raids of the Picts and Scots. A road, afterwards known as the Stanegate, connected them. Agricola penetrated yet farther north in A.D. 81 and, to keep the constantly-attacking enemy at bay, built another outlying chain of forts from the Forth to the Clyde.

When the emperor Hadrian came to Britain, in A.D. 121, he ordered a more complete chain of defences to be built, and planned a great stone wall stretching from coast to coast, north of the Stanegate and the



Courtesy of 'The Listener"

A mighty defensive work built by the Roman conquerors of Britain—Hadrian's Wall which stretches for 73 miles from Newcastle-upon-Tyne to Solway Firth. Some of this wonderful structure is in a good state of preservation, as may be seen from this section of it near Housesteads—the Roman Borcovicium

forts built by Agricola. To mark the boundary of Roman territory Hadrian ordered an earthwork and a flat-bottomed ditch or "vallum" to be made south of the defence wall. And, as additional strength, a ditch ten to fifteen feet deep and thirty-five to forty feet wide was dug on the northern side. It was a stupendous task and Hadrian did not remain in Britain long enough to see it finished. The ten-feet vallum and extra forts were built first, but even these were not impregnable, and the great continuous stone wall was the final effort of Roman military strategy.

Hadrian's Wall was originally eighteen to twenty feet high if one includes the battlements, and it was at least twelve feet to the rampart walk. But it is its breadth which has given it the solidity to weather the centuries. The foundation is nine feet six inches wide, and the width of the wall at the top varies from six to eight feet.

The wall was built in sections, each under the command of a centurion. Just as commemorative tablets and foundation stones are set into modern buildings, so these centurions each built into his section a stone inscribed with his name and rank. This sectional method of building most likely accounts for the sudden differences in width of the wall in various places. Firm foundations of flat flagstones, laid on rock where possible, ensured a permanency to the great boundary defence. Wedge-shaped sandstone blocks form the flanking walls, the point of the wedge being pushed into the rubble and mortar core in order to bind the whole firmly together.

The wall was built to climb the line of higher country whence the sentries had a better view of an approaching enemy. The highest hill it tops is Winshields, 1,230 feet. Between Walwick and Sewingshields, whose names betray their origin ("wall-wick" and "sheals" or cottages by the "sough" or ditch), the wall runs along the edge of a precipice, the steep scarp of which confronted attackers from the north. Farther west by Limestone Bank, both the vallum and wall-ditch were cut through solid basalt.

By permission of H.M. Stationery Office *Photo: Ordnance Survey—Crown Copyright Reserved*

Of the fourteen forts originally built along Hadrian's Wall, only four can now be seen in any detail. From the air, however, the disposition of the various buildings and the surrounding ditch stand out with great clarity, as this vertical photograph of Cilurnum (now Chesters) well shows. Immediately above the outlines of the fort is the bath-house, the remains of which are illustrated on the opposite page

Courtesv of "The Listener"

The fort of Cilurnum on Hadrian's Wall has been skilfully excavated and it is possible to distinguish the praetorium, walls and gateways in the thresholds of which grooves made by chariot wheels are discernible. Here is the bath-house which stands between the fort and the river, as can be seen from the air photograph opposite

The Roman soldiers who were the constructors had to be quarrymen as well. In Fallowfield Fell there is still a series of Roman quarries which supplied material for the wall. One soldier-quarryman has immortalized himself by carving his name, "Petra Flavi Carantini," on the rock.

Where Dere Street, the great Roman road from London, met the wall, a gate known as the Portgate was built to allow soldiers, supplies and chariots to reach the more distant and irregularly garrisoned forts lying between the Forth and Clyde. One of the most remarkable features of the work was the Roman bridge that continued the barrier over the North Tyne. There are traces of two bridges, the later of which was wide enough to carry the military way afterwards called the Stanegate.

Hadrian's Wall stretches for seventy-three miles, from Wallsend, outside Newcastle, to Bowness on Solway Firth. Fourteen forts were built into the wall, but the remains of four only of these can be satisfactorily studied to-day: Cilurnum, now Chesters; Borcovicium, now Housesteads; Aesica, now Great Chesters; and Amboglanna, now Birdoswald. The area enclosed by each fort varies, some being four or five acres in extent and others but half that size. All are parallelograms in plan, with rounded corners, enclosed by a five-feet-thick wall and surrounded by a ditch. Each had four gates, opening to the north, south, east and west.

The stone thresholds of the gateways at Cilurnum and Borcovicium are grooved by the constant passage of chariot wheels, the width being exactly that of the ruts found in the streets of Pompeii. The greatest care seems to have been bestowed on the granaries of these forts. The floors were supported on dwarf stone pillars to allow circulation of air and prevent damp, while the whole was strongly roofed with sandstone slabs. Borcovicium was often destroyed by the enemy and shows signs of having been rebuilt several times during the 400 years of Roman occupation. There are at least four floor levels, each of the later erections having been built on the debris of an earlier one.

Photo T. Butler

Photo. Naton

Originally, there was a large number of watch-towers and gateways along the Great Wall of China, the majority of which have now fallen into decay. This ruined tower and section of stepped wall is at Ling-Kao, while above is a well-preserved gateway

Such names as Bloody Gap and Thorny Doors bear witness to the fierce assaults made against the defenders of the wall. The present inhabitants still regard the wall as an important boundary. All farms and villages to the north of the wall are spoken of as being "out-by," while those sheltered by it on the south are "in-by." Besides the irregularly spaced forts there are many "mile-castles" and sentry turrets at more regular intervals. Three other forts, too, lie close to the south of the wall. Since Aulus Platorius Nepos, Hadrian's commander-in-chief who carried out most of the actual construction, did not incorporate them in the wall they are presumed to belong to Agricola's earlier chain of forts.

The lives of soldiers guarding this lonely outpost of the Roman Empire were made more agreeable by the fact that their wives and families also lived in the forts. Many bronze, silver and enamel trinkets have been unearthed nearby. Local tradition has it that it was the Romans who first brought to these northern hills the tiny, onion-like chive. Patches of them, like fine grey-green grass, are often to be seen growing on flat rocks there. Excellent bath-houses were built near each fort, the best preserved being that at Cilurnum or Chesters.

Severus Repairs the Wall

Some 80 to 90 years after the building of Hadrian's Wall the whole extent was badly in need of repair, owing to the many raids of the Picts. Wall, forts and turrets underwent a thorough reconstruction under the emperor Severus. The repair work was so well done that it is only with difficulty that the newer construction can be distinguished from the older. And so for another 200 years, until their recall to Rome in the fifth century, the walls were occupied by the Roman legionaries.

For a time during the period of occupation the work of guarding the border must have been very difficult. In A.D. 142 the emperor Antoninus Pius, through his general and governor Lollius Urbicus, found the incessant successful raids from the north too frequent to permit of the peaceful development of the south. He took the offensive and advanced from the Tyne and Solway frontier to the narrower thirty-mile isthmus between the Forth and Clyde. Here was the series of forts that had been built by Agricola in A.D. 82. Antoninus determined to strengthen the new border and built a rampart, stretching from coast to coast, which was protected by a ditch to the north facing the enemy's territory.

The rampart was made of turves and in some of its eastern section was merely a bank of clay. The nineteen forts it connects vary in size and strength. Some enclose only one acre of ground, whilst the area of others is almost seven acres. The fort-ramparts also were not uniform. Balmuidy and Castlecary were walled with stone; whereas the ramparts of Old Kilpatrick, Bar Hill, and Rough Castle were of sods, and those of Mumrills of clay. Rough Castle is by far the sturdiest. Its ramparts and ravelins and series of defensive pits suggest that it was an Agricolan fort. The pits were plainly intended to break the enemy's charge and seem to have been provided with stakes to impale the invaders.

Names in Dumbartonshire and the other counties traversed by the wall still hold the memory of the Roman occupation. Kirkintilloch grew up on either side of the great rampart, and the Gaelic meaning of its name is "the fort at the end of the ridge."

Sixteen years after the construction of the rampart a revolt broke out in the north of England. Quelled at first, it broke out again in the country between the two walls. Not until the year 208, when Severus in person came to conduct a punitive expedition against the Picts of Caledonia, was peace made. Although the Picts retired to their fastnesses, Severus found it more politic to abandon the Antonine Wall, and he therefore fixed Hadrian's Wall as the northern limit of Roman power in Western Europe.

Great Wall of China

China is a country of walls. The greatest one was built by the emperor Shi Hwang-ti. It had been standing some three centuries when Hadrian laid his plans to protect the British border, and to-day, despite its much greater length, it shows far less of the ravages of time. The poetic Chinese name of this barrier is the "Wall of Ten Thousand Miles." Its actual length is 1,500 miles if we take into account the twists and turns that it makes as it follows the line of hills and valleys. Parts of the walls existed long before Shi Hwang-ti in his pride determined to build the mighty rampart.

The Chinese were ever on the watch for the coming of fierce tribes from the north. These—the Huns and the Mongols—lived in a bleak country visited by long, severe winters, and looked with covetous eyes upon the fertile, well-cultivated lands of China. To secure their frontiers, the Chinese built chains of forts along them. Each state, in fact, had its own frontier forts and defensive walls, and it was only under the despotic rule of Shi Hwang-ti that the states were unified and the forts and frontier walls abandoned.

In the year 215 B.C. the emperor dispatched 300,000 men against the Huns who then were rapidly subjugating the Chinese border tribes in the north. The land lying within the loop of the Yellow River (Hwang-Ho) was conquered and a connecting wall was built along the line of existing

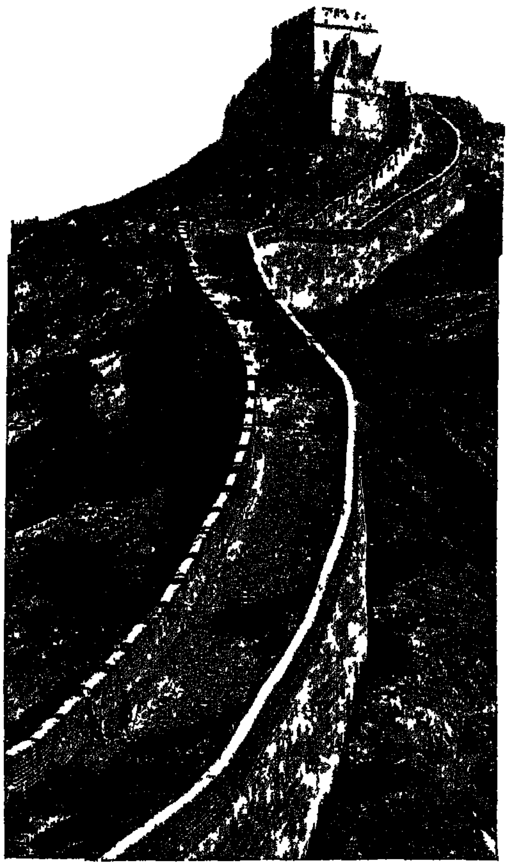


Photo the late H. G. Ponting

A notable feature of the Great Wall of China is the skilful manner in which the builders selected the most advantageous contours when carrying the wall over a hill or up a mountain-side. This is clearly seen in the almost perfect sector here shown

fortification on the northern frontier. This was the beginning of the Great Wall. Shi Hwang-ti appears to have been a man who did everything on a grand scale. He planned to build a wall with a length of "one-twentieth the circumference of the earth." Perhaps it was his hope to leave an imperishable record in stone, and it is certainly true that for over 2,000 years his memory has been kept green. The wall has doubtless been a useful bulwark,

but it can scarcely have been worth the colossal expenditure of human life and labour that went to its making.

It is said that the emperor pressed into service for building the wall one-third of the able-bodied men in his kingdom. Some 700 miles of the structure were built in his own reign and the rest under subsequent emperors. The structural character of the wall is simple. Two outer walls, the lower part of stone and the upper of red brick, hold a central core of granite blocks topped with hard-packed earth. There is a brick, crenellated parapet and at about every hundred yards a fortified tower was constructed.

The wall was twelve to fifteen feet wide, and varied in height from eighteen to twenty-one feet. At the Nankow Pass, the best preserved sector, it is wider and higher than in others. Here it reaches thirty feet in height, and is twenty feet broad at the base. At Lan-chow-fu and Liang-chow-fu the Great Wall, following the mountain contours, rises to over 4,000 feet above sea-level.

Work in the desert regions had its special difficulties, and here triple walls became necessary to withstand the encroaching sand. Yet for all its strength and vastness the great barrier did not prevent the coming of Genghis Khan, the Mongol chief from the north-west. The weakness of the wall, however, lay as much in the soldiers who defended it as in the inadequacy of the structure itself. Chinese poets lament the trail of war, "when dykes of the Great Wall brimmed with blood" and the wounded died of cold.

Such a gigantic work could never have been undertaken except by an absolute ruler with almost unlimited supplies of forced labour to command, and this is true of most of the great edifices of ancient times, that consumed the labour of centuries in their accomplishment. The Great Wall of China stands as a monument to the toiling multitudes who raised it, no less than to the vanity and pride of an ambitious emperor.

Unlimited labour must have been at the command of those who built the massive walls in South America that formerly were attributed to the Incas. Of their origin little is known, and most of them are entirely unlike the later Inca structures. Walls of long-

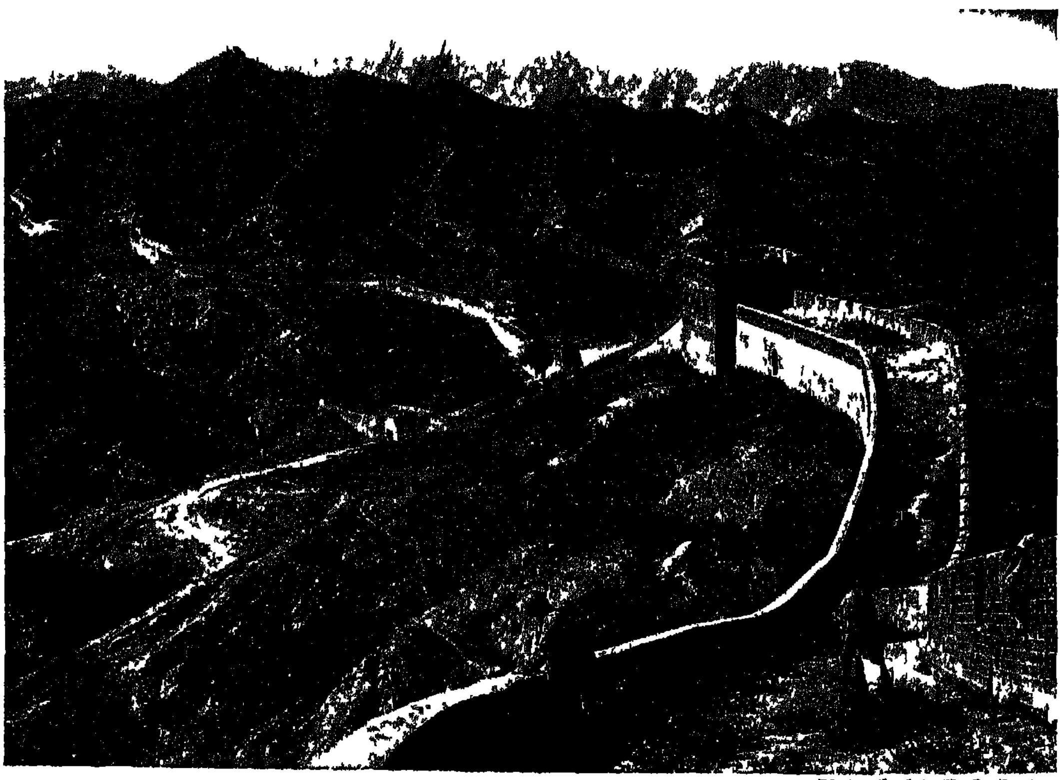
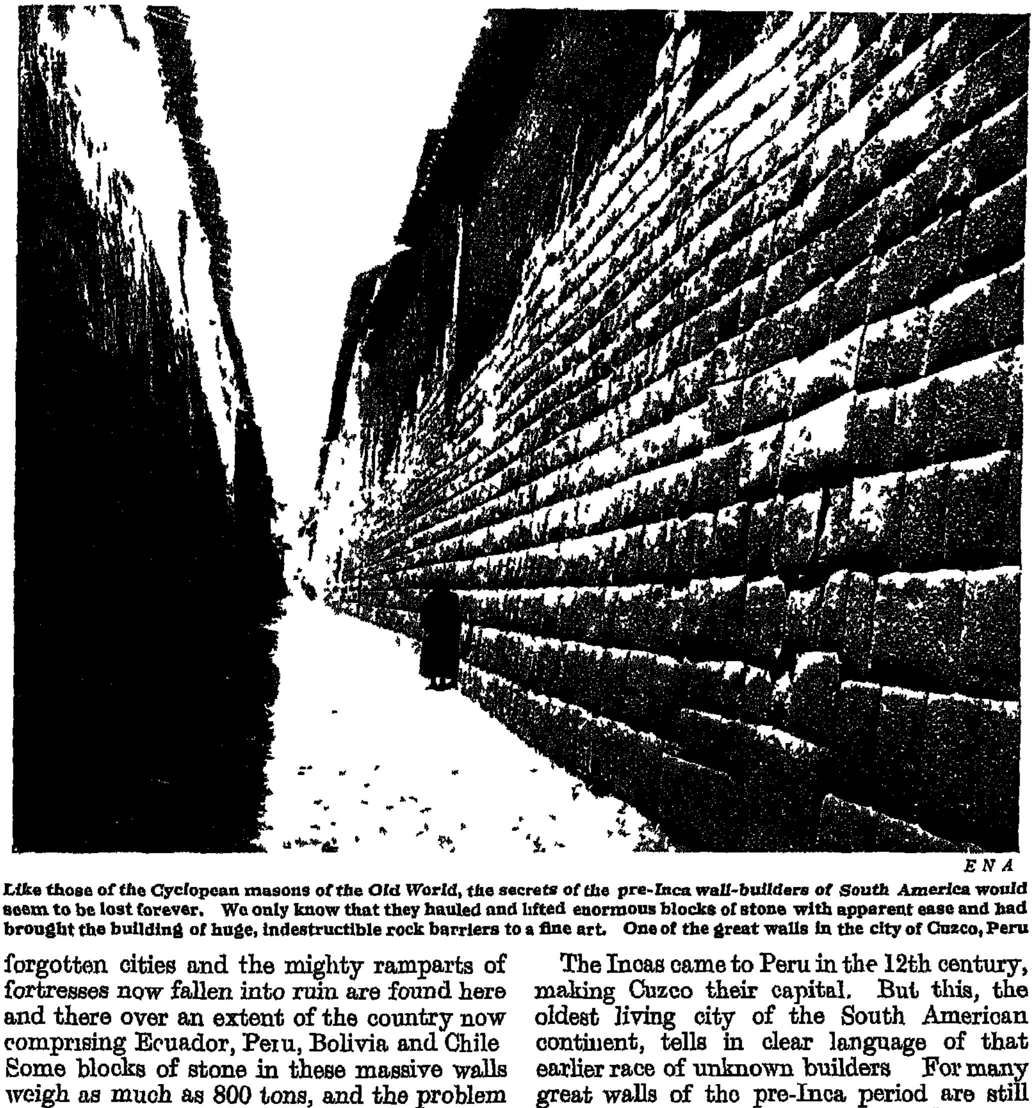


Photo: the late H. G. Ponting

At the Nankow Pass, the Great Wall of China is 30 ft. in height and 20 ft. broad at the base, and here also the battlements and watch-towers are in excellent condition. This fine panoramic view of the wall winding its serpentine way over the mountains eloquently suggests the immensity of the task that faced its builders



E N A

Like those of the Cyclopean masons of the Old World, the secrets of the pre-Inca wall-builders of South America would seem to be lost forever. We only know that they hauled and lifted enormous blocks of stone with apparent ease and had brought the building of huge, indestructible rock barriers to a fine art. One of the great walls in the city of Cuzco, Peru

forgotten cities and the mighty ramparts of fortresses now fallen into ruin are found here and there over an extent of the country now comprising Ecuador, Peru, Bolivia and Chile Some blocks of stone in these massive walls weigh as much as 800 tons, and the problem of how they were put into place is a baffling one. The feat of these unknown masons is even more amazing when we consider *that their tools were of copper, and that the* massive blocks of stone were held together without cement.

The Incas came to Peru in the 12th century, making Cuzco their capital. But this, the oldest living city of the South American continent, tells in clear language of that earlier race of unknown builders For many great walls of the pre-Inca period are still standing. The Incas, too, were wall-builders, but generally they raised their walls upon the foundations of those built by their predecessors. The Spanish conquerors in turn built their own tawdry stucco houses upon the Inca structures.

CHAPTER XXV

WHEN THE WORLD WAS YOUNG

IN the last year of the 18th century a fisherman plying his craft near the mouth of the river Lena, in the dreary wastes of northern Siberia, was astonished by the sight of a large uncouth mass projecting above the melting snow and ice, and bearing some resemblance to an animal form. When the ice had melted sufficiently, the carcass of a ponderous, elephant-like creature was disclosed, bearing long, curling horns and clad

in a shaggy pelt of reddish wool, and with sightless eyes still glaring from their sockets upon a world on which they had last gazed many, many thousands of years before. Later, when the fisherman had mastered the awe he had felt at this apparition, he unceremoniously hacked off the creature's tusks and carried them away, leaving their despoiled owner in the snow, to be gnawed from time to time by hungry wolves and dogs.

By the year 1806, reports of this ancestral elephant—for such it was—had reached the outside world, with the result that the mangled remains of the monster were freed from the ice and dirt and carefully conveyed to St. Petersburg, where they were exhibited in the museum as a priceless trophy.

The Home of the Mammoth

Though the number of mammoths with completely preserved tissues is not large, their bones and tusks are scattered in profusion all over the northern coastline of Siberia, while they also occur abundantly in Europe and America—facts which argue a very wide distribution of these early elephants. Countless teeth of mammoths and many of their tusks have been dredged from the bottom of the North Sea, and numerous fossilized remains of these hairy monsters have been found in Great Britain, even beneath the streets of London.

The mammoth resembled in a general way the modern Indian elephant, though its tusks were much longer and more massive, displaying a strong upward and inward curl. Moreover, the mammoth, as we have seen, wore a thick, shaggy coat of wool, interspersed with long hairs and coarse bristles; and in this connexion it is interesting to note that in the new-born young of both the African and Indian elephant this ancestral pelt is still perpetuated, although the hair is lost after a few weeks.

There were other important ancestors of our elephants that were much less like the modern species and approximated more to a primitive type than did the mammoths. There were the mastodons, of which there were many kinds. In the early mastodons we see the shadowy beginnings of the characteristic elephant form; the face, for instance, was very long and pig-like, while the chin was not only extended into a snout, but bore a pair of short tusks projecting straight forward and crossing the long upper tusks, between which lay the short trunk, or rather, elongated upper lip, for in that primitive creature it was little more than this. This early mastodon—Tetrabelodon, to give it its scientific name—had evolved by slow changes from proboscidians more and more remote, with which we cannot concern ourselves here; and from Tetrabelodon, by changes equally slow, were to evolve the most completely developed mastodons of Europe and America. The tusks grew longer, the trunk became enormously enlarged, while the lower jaw was shortened, so as to allow the trunk to hang down vertically—and the mastodon began to resemble the mammoth of the Russian museums and the elephant of to-day, though it was larger, heavier and more powerful than either.

How was it that these Siberian mammoths were, so to speak, cut off suddenly in their prime—well nourished and uninjured, with food still in their mouths and stomachs and with all their physical functions unimpaired? It needs little effort of the imagination to reconstruct the scene. The great mammoths, it is thought, were browsing placidly on the desolate tundras within the Arctic Circle, when they were unfortunate enough to wander into a bog, where their struggles were ineffectual and their vast weight speedily dragged them to destruction.

The last mammoths held their own in northern Siberia until a period which has been estimated at about 15,000 years ago, and then they became extinct. However, 15,000 years is but a second in geological time, and the mammoths are among the latest of all extinct creatures. We have introduced them far out of their proper order because they form what is perhaps the most complete and dramatic link between the world of to-day and that of the remote past; and now we propose to go back to a vast antiquity, when the predominant forms of life were very different from those that now surround us.

Earliest Forms of Life

The earliest forms that life took upon our planet can only be guessed at, for the earliest reliable fossils with which we are acquainted —and they are of an inconceivable age— are those of creatures already highly developed (though humble enough in comparison with the higher animals that arrived later on the scene), thus hinting at a very long life-history, so long, in fact, that, as one eminent authority has said, the creatures represented by these early (Cambrian) fossils seem to be "as far removed from what must have been the first forms of life, as

the living forms of this remote period are distant from the creatures of to-day." It is an accepted truism that life began in the sea, and these earliest fossils are all of sea creatures; animal life had not yet invaded the land in that dim period in which the so-called Cambrian rocks were being laid down grain by grain on the floor of the sea.

Let us try to imagine ourselves standing by the shore of the Cambrian sea as it beats monotonously upon the stones and rocks. rare occasions when a volcanic cone blows off its summit, or when the groaning rocks are rent and split by an earthquake. Yet at our feet, as we stand by the seashore, there is a whole world of life. Though there are no fishes, or any creature of sufficient development to possess a backbone, there are many creatures related to forms with which we are familiar to-day. There are sponges, for example, and jellyfishes, starfishes, corals and marine worms. Shellfish are well re-

Courtesy of the Leningrad Zoological Museum and Intourist Ltd.

Preserved in Arctic ice for countless years just as it sat down and died—the huge Siberian mammoth discovered near the mouth of the River Lena and now in the Zoological Museum at Leningrad. Rarely have these great beasts of prehistoric times been found in such a perfect state

Besides ourselves there is not another living creature on the land; even if we were to range over the whole earth, we should not find even the smallest, humblest land animal: if we were to scrutinize the rocks and the gritty, sandy earth through a microscope, we should find nothing but rocks and earth. There is no vegetation, no trees, flowers, leaves or grasses, and the sun glares crudely down on the naked earth. And, but for the tossing of the sea, there is utter stillness and silence, such as would soon break down the nerves of any ordinary human being. Inland, the silence is appalling; it is broken only when the wind gathers force and howls mournfully over the naked earth, or on the

presented, and there are also creatures related to our squids and cuttlefish.

Whether seaweed was known in the Cambrian seas is not clear, for the fossils that have been claimed as those of seaweed may just as well represent worm tracks or casts; but there was a plentiful "vegetation" formed by the long, swaying stalks and feathery heads of the sea-lilies, or encrinites which, though most plant-like, were really not plants at all, but a sort of star-fish. Far different, however, is the case of the Cambrian creatures called trilobites, which have long been quite extinct all over the globe, but which swarmed in these early seas. They were many-legged creatures

plated with horn, with bodies composed of numerous jointed rings and displaying in many cases a strong resemblance to our wood-lice, with which they were at one time considered to be allied, though probably they are more nearly related to the spiders, scorpions and king-crabs. Some of these curious crustaceans were quite diminutive, but others attained a length of nearly two feet. They wandered about over the bottom of the Cambrian sea, feeding upon worms; some of the trilobites were quite blind, but others had large and well-developed eyes.

We shall now take leave of the world of Cambrian days, and take a rapid glance at the periods immediately succeeding, all of which were several millions of years in duration.

Photo British Museum (Natural History)

Reconstruction of the Mammoth (*Elephas primigenius*) which stood 9-10 feet at the shoulder. Its tusks are known to have reached a length of 12 feet 6 inches

So we pass into the Ordovician period, in which the variety and abundance of life in the sea had increased enormously. Molluscs were very plentiful, especially those known as brachiopods, or "lamp-shells," which are particularly interesting, since they have modern descendants which have deviated but little from the ancient forms. The cephalopods—the order including the squids and octopods—were also very active, and some of them were of huge proportions, with straight shells fifteen feet or so in length and a foot in diameter—veritable giants of the Ordovician seas. Trilobites attained their greatest development in this period and swarmed everywhere, while very prominent, too, were the so-called graptolites, colonies of polyps taking the form somewhat of a quill pen. There were many other lowly sea creatures, too numerous to mention, but most interesting of all, perhaps, are very ancient forms of the creatures called ostracoderms—small, uncouth ancestors of the fishes—which in this period begin to display the earliest known rudiments of a backbone.

In the Silurian period, to which the Ordovician gave place after enduring for millions of years, trilobites and graptolites still flourished, together with numerous shellfish, starfish, corals, worms and many other forms of sea life. There were also the curious scorpion-like creatures called eurypterids, which were sometimes four or five feet in length. At about this time, too, Nature was beginning to make real fishes, the most highly organized of all creatures that had lived hitherto. These included the ancestors of the sharks and dogfish, which have soft, cartilaginous skeletons in place of bone, and thus have left in the rocks only their teeth and the hard, tooth-like processes which cover their skin; the

armoured ostracoderms, the first creatures to show any hint of a backbone, were also characteristic of the Silurian seas, where they swam about among the gigantic trunks—up to two feet in diameter—of monstrous seaweeds. By now, plant life had definitely established itself on land, but for long ages it was to comprise only humble forms, such as ferns, mosses and algæ.

The next geological period was the Devonian, which has been called "the age of fishes," for unmistakable fishes were by now swimming in the sea, though they were very unlike our modern conception of a fish. Those known as ganoid fishes were clad, for instance, in hard, smooth, bony scales that interlocked with one another to form an impenetrable armour. Their tail fins were divided usually into two unequal lobes, like that of the shark, a creature which they further resembled in their boneless internal structure. In Africa, Australia and South America are found to-day the freshwater, so-called "mudfishes," which are of great interest not only because they breathe by means of lungs as well as gills, but also as being the last survivors of a race of fishes allied to the ganoids.

Photo: British Museum (Natural History)

As it probably appeared in life—*Mastodon Americanus*, which was shorter of limb and more massively built than the true elephants

There was also a remarkable group of fishes in the Devonian seas that had the singular faculty of nodding their heads up and down, which no modern fish has the power to do. One species, at least, of these nodding fishes was quite formidable, reaching about twenty feet in length and being armed with powerful jaws about two feet long, terminating in a sharp beak. Skulls and jawbones of this creature, which is known as Dinichthys, are preserved in the Natural History Museum at South Kensington. In the Devonian rocks is also found the Pterichthys, a remarkable ostracoderm which has been described as resembling a tortoise's shell with a fish thrust into it, for the bulk of its body was composed of hard, bony plates like those of a turtle, which terminated in a flexible scaly "tail" equipped with fins. Ancestral forms of sharks became very numerous at this period, and there must have been many, many strange denizens of the sea whose appearance we shall never be able even to guess at, since their remains have become quite obliterated in the long march of time.

The Devonian seas were rich in other forms of life besides fishes. Lamp-shells and their allies were extremely numerous and diverse, the ancestors of the cuttlefishes were

developing apace, and reef-building corals were creating land out of the sea, just as their descendants are still doing to-day. On the other hand, the trilobites began to degenerate and decline in numbers; while the graptolites, formerly so plentiful, died out entirely during Devonian times.

The dry land at this time was no longer the lifeless, dreary place which we saw in Cambrian days. It was plentifully covered with vegetation, often rank and dense, but of a most strange and seemingly weird type, such as we shall see carried to full development in the great coal forests of the next era. Ferns, mosses and gigantic horsetails, twenty feet or more in height, grew on the borders of the swamps, and there were also coniferous trees, related to the Araucarias, although plants producing flowers were entirely absent.

The Devonian period persisted for some millions of years, and then passed imperceptibly into what is for many reasons one of the most interesting of all the geological eras and certainly the one which has been of most service to mankind, for it was the era at which a great part of the coal measures and oil deposits of the world were being laid down, upon which so many aspects of our modern civilization are dependent. During this, the Carboniferous period, life was becoming increasingly fuller and more varied, though all its diverse forms must still have been strange enough in comparison with anything we know to-day.

Laying Down of the Coal Measures

Let us for a while imagine that we have gone back in time many millions of years and are actually looking upon the Carboniferous landscape, just as we stood in fancy by the desolate Cambrian seashore, when the land was not tenanted by a single living thing. (A remarkable portrayal of a Carboniferous forest is given in a colour plate at the beginning of this volume.) What a difference is seen now in our surroundings! We are standing in a dense, swampy jungle. Gigantic ferns lift their spreading fronds sixty or seventy feet above the ground, and loftier still are the huge club-mosses—ancestors of the tiny, creeping club-mosses of our hills and moors—which stand like forest trees and measure five feet or more through the trunk. Here are the forebears of our horsetails—but they, too, are large and ponderous trees. There are also enormous araucarian trees—conifers related to our "monkey puzzle"—and slender climbing plants that drape and encircle their bigger brethren, much as do the tropical lianas of to-day. *See* FRONTISPIECE.

There is a sombre and monotonous aspect about this primeval forest that depresses the spirits. For one thing, we find a marked similarity in most of the plants; their branches almost uniformly cumbrous and club-shaped and springing from the trunk in regular whorls. We miss, too, the thin, broad leaves of our own trees such as oak, elm and beech, which cast such a cool and grateful shade in modern forests. In the Carboniferous jungle most of the leaves are tiny, narrow and spine-like, so that they can do little to keep out the light of the sun. Then there is not a single bloom, or the promise of one, in the whole of this ancient jungle, and the fragrance of flowers is a delight which is as yet unknown. Yet there is a multitude of creatures that live, and presumably are happy, in this fantastic forest. Crickets chirrup merrily in the sunshine, bugs and beetles run busily about in the undergrowth, spiders prowl warily up and down the fern trunks, loathsome cockroaches of enormous size scuttle over the roots that spring from the black ooze, where far below, generation upon generation of fallen trees and dead ferns are beginning the lengthy operation of turning themselves into coal. There are also scorpions, locusts, stick-insects, white ants, snails, giant may-flies, and preposterous dragon-flies with a wing-span of two feet.

This period must have been a veritable insects' paradise, for they had few enemies of any kind; birds, for example, which constantly decimate their ranks to-day, were non-existent, and the first song of lark or thrush was not to be heard for many millions of years. Here there are no bees—nor butterflies and moths, for that matter—for there are no flowers to offer them nectar.

Volcanoes and Earthquakes

Just as we are thinking how monotonously still the forest is, save for the occasional voices of the crickets and the drowsy murmur of the wind in the fronds of the great ferns above us, we are startled by a roar as of a monstrous explosion, and through the tree-tops we see the sky lit up with an angry glare. It is one of a multitude of volcanoes that has burst suddenly into eruption and is flinging red-hot rocks and torrents of ash towards the heavens; while a flood of burning lava pours down the mountain-side and begins to devour the forest. At the same time, the earth shakes ominously, and

everything conspires to bring home the fact forcibly to us that our earth, though already of an inconceivable age, is still internally in a very unsettled condition.

The earthquake and the eruption cause terrible havoc; and the noise made by the most savage elements of Nature, unmixed with any cry of man, bird or beast, echoes through the forest in an appalling, unearthly din. Hundreds of the monstrous plants crash to the ground, where they lie like contorted, expiring giants; while curious creatures that we had not noticed before move about in alarm in the most swampy places and near the banks of sluggish creeks. These bear a general resemblance to newts and salamanders; they have long bodies and tails, and their heads are encased in bony armour. Some of these creatures are quite small, only a few inches in length, though there are others that measure seven or eight feet. Their legs are weak, or else have not been developed—in which case their bodies are serpent-like—for they have not long taken to walking about the land, and they are still just as much, or even more, at home in the water as on *terra firma.*

First Backboned Land Animals

These amphibians are believed to have been the first vertebrate, or backboned, land animals; it is probable that they developed slowly from fishes which contracted a habit of floundering about at low tide upon the seashore and exposed banks of mud, until they had become quite used to living outside the water. The young of these amphibians hint at the origin of their race, for they were fish-like "tadpoles," living entirely in the water and provided with gills.

While life was thus becoming more abundant and more complicated on land, it was developing with no less certainty in the sea. Fishes of all kinds were now plentiful, and they were invading inland waters. Perhaps the most dominant fishes were the sharks, with terrible rows of teeth which they used to crush up crustaceans and shellfish in enormous numbers. The brachiopods—lamp-shells and their allies—though still important, began to decline; while the trilobites, formerly so numerous, almost entirely disappeared. There were also sea-lilies, sponges, worms, sea-urchins and vigorous coral colonies in the Carboniferous seas, all becoming gradually more and more like the forms in which we know them to-day.

Though the important Carboniferous period is so named owing to the occurrence of coal in the strata of rocks laid down during this time, we must not imagine that all the Carboniferous rocks consist of coal. On the contrary, coal is present in the majority of the deposits to an extent that forms only a small proportion of the whole, and the bulk of the Carboniferous layers is composed of limestone, sandstone, shale, clay, marl and other "rocks." However, coal remains the most important to man of all the Carboniferous, or indeed any other, deposits, and we propose to trace briefly its formation from the uncouth ferns and club-mosses of the primeval forests.

How Coal has been Formed

As is the case with most of the natural causes that have shaped our earth and made it what it is, the laying down of coal did not come to an end at a remote period, but is still proceeding actively—as, for instance, in the peat bogs and "mosses" which cover a considerable part of northern Europe. As everybody knows, peat is a dark, fibrous substance, consisting almost entirely of dead vegetable matter, preserved from decay by chemical action and pressed into a compact mass by the weight of the layers above it. Peat, which is very soft and loose compared with coal, is formed fairly rapidly, and in some places a layer three feet thick may be the accumulation of only thirty or forty years; other peat bogs, however, are of much slower growth, and even at a depth of only a few feet we may find in some of them stone implements, the remains of dug-out canoes, and other relics left by primitive men who roamed over the locality in the far-off days when the dry peat moss was a lake or swamp. But a vastly greater time still would be required for the formation of a bed of coal of this depth. Given sufficient time to do so, however, the peat would pass by imperceptible changes into coal.

But we must not conclude that the climate of the ancient coal forests was necessarily hot. In fact, geologists are of the opinion that the climate prevailing in those days was very similar to that of the temperate zones of the earth to-day, and that the Carboniferous vegetation owed its rank and luxuriant growth to other agencies than that of hothouse warmth. The natural history of coal is a subject of great complexity but the general manner in which coal was formed is easy to understand from the present conditions to which we have just referred. The dead and fallen horsetails and club-mosses formed an accumulation that was

increased by debris washed along by streams and floods. The level of the land gradually subsided—as it was particularly wont to do in Carboniferous days—and the sea took the place of the former swamp or jungle. Ages passed, during which a bed of sandstone or limestone was deposited, grain by grain, upon the fallen forest; then the geological pendulum swung back again, the sea receded, a new forest flourished upon the grave of the old one, and gradually a second layer of vegetable refuse was deposited. In some localities this gigantic ebb and flow occurred many times, leaving an indelible record in the rocks in the form of layers of clay or sedimentary rock alternating with the seams of ancient plant remains—altered out of all recognition by stupendous pressure—that we know as coal.

Critical Period in Earth-History

We must leave the interesting Carboniferous period and pass to the Permian, in which we shall find some new creatures altogether. This seems to have been a critical period in the history of our earth, and unfortunately there are many perplexing blanks and gaps in the story told by the rocks, which geologists would dearly love to be able to fill.

In the sea, types more and more like modern creatures were being evolved; the fishes were beginning to look like those of to-day, while the trilobites died out entirely in this period. But the most significant changes were taking place on land, where the first true reptiles—forerunners of a race that was to become predominant in succeeding ages—were putting in an appearance. Many of them were very fearsome and uncouth, but in these respects they lagged far behind some of their descendants.

Some of the Permian reptiles bore a resemblance to the crocodiles and large lizards of to-day, and several repulsive forms are known that had a lofty crest with a saw-like edge running along the back, supported on spines that grew from the backbone. These reptiles, of which the best known is the creature called Dimetrodon, had also ferocious teeth and claws. The newt-like amphibians were very active, too, during Permian times, and they have left their footprints clearly printed in the sand that has turned in time to rock.

With the last Permian deposits the first great era in the history of life comes to an end; it is known as the Palæozoic, or era of ancient life, and it is succeeded by the Mesozoic, or era of middle life, which begins with the Triassic rocks. During Mesozoic times the earth's crust had become more or less settled, and it was free from great convulsions such as had torn and twisted the rocks in earlier times. Most of the great volcanoes, too, had become extinct or inactive. Judging by the relative thickness of the strata, the Mesozoic era endured only about a quarter as long as the Palæozoic had done, but it was a time of more vital changes. Primarily, it was the age of great reptiles—in many ways the most remarkable of all the beings that have inhabited the earth. We meet with quite large forms in the Triassic rocks. There was a lizard-like animal called Pariasaurus, for example, whose remains were found some years ago in large numbers in the cliffs of the River Dvina, near Archangel. This was a large animal—about eight feet from nose to tail—but its numerous small teeth show that it was a harmless vegetable feeder, which doubtless fell a prey to the savage appetite of its carnivorous fellows. One of the latter, Inostranscvia, had a skull that measured two feet in length, and its jaws were set with terribly long and sharp fangs.

It was during Triassic times that certain freshwater reptiles developed the habit of swimming down the rivers into the open sea, and these were the ancestors of the great fish-lizards which we shall meet in a later period. Carnivorous reptiles resembling our crocodiles were numerous in Triassic times, while turtles also became well developed during this period. It is in the Triassic rocks, too, that we find the earliest remains of dinosaurs, the great land reptiles which were to make the world such a fantastic and terrible place to live in during the next two geological periods.

The First Mammals

But most important of all Triassic productions were the earliest mammals, that class of animal to which all the higher creatures—including man himself—belong.

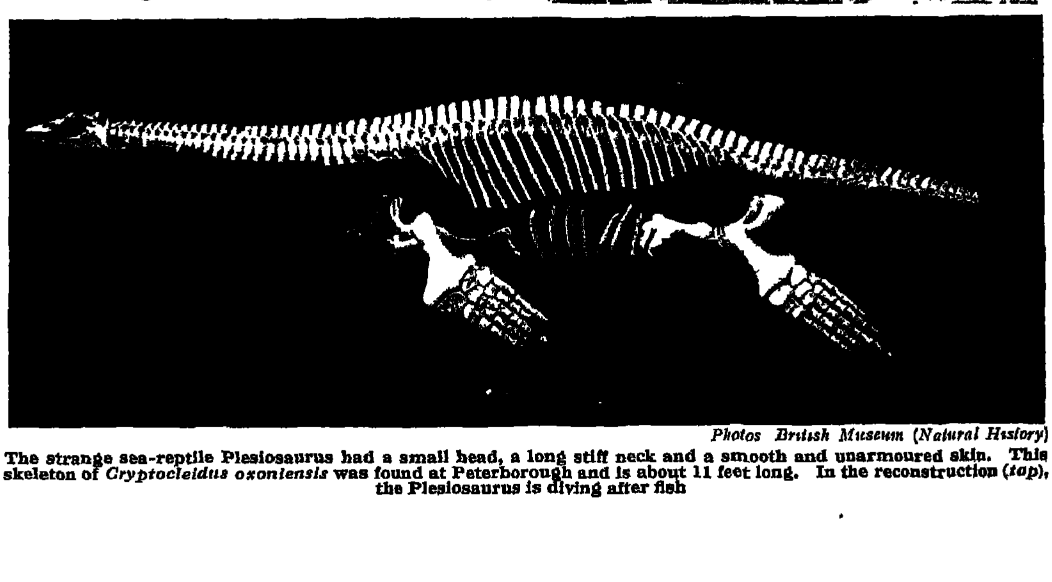
The next period, the Jurassic, has been not inaptly termed "the age of reptiles," for at this time they were lords of land, sea and air; never before nor since have reptiles attained such dominance, or individually such a colossal size. Ranging through the seas, for example, were the great ichthyosaurs, or fish-lizards, which had streamlined bodies like those of true fishes, long, narrow jaws set with many teeth, large flippers and enormous eyes. The largest

of these creatures measured thirty feet or so in length, and they were singularly like modern porpoises and grampuses, though these, of course, are mammals.

The Plesiosaurus was another weird reptile of the deep. This creature had a round, elongated body, something like the hull of an early submarine, from which projected a very long, slender and tapering neck bearing a head that was small and snake-like, with jaws furnished with numerous conical teeth. The Plesiosaurus swam rapidly through the water by means of its four large paddles and long, muscular tail; and probably it could seize lizards and other animals from the rocks when coasting along near the shore; or snap fishes and molluscs out of the water; or with equal facility could dive far below the surface and thrust its long neck into the intimate recesses of subterranean caves and chasms in search of particular dainties. There were several species of Plesiosaurus, some of which were only six feet or so in length, while others measured fully forty feet from head to tail.

If we take the restoration of Plesiosaurus which we here show in our sketch, add two pairs of stout limbs instead of swimming paddles, lengthen the tail and make the whole body somewhat more bulky, we shall have a very fair conception of the great dinosaur known as Ceteosaurus, and also of the closely similar Brontosaurus and Diplodocus, all of which must have been truly fearsome-looking beasts, though actually they were comparatively harmless vegetarians. These dinosaurs walked equally upon all four feet and, it is thought, browsed upon succulent water-weeds; it has been suggested that they walked along the bed of the sea or river keeping their disproportionately tiny heads just above the water.

Probably they spent the greater part of their time in this fashion, for, as we shall see, terrible foes awaited them on land. There is a cast of a skeleton of Diplodocus, fashioned after actual remains, in the Natural History Museum, London; it is no less than



Photos British Museum (Natural History)

The strange sea-reptile Plesiosaurus had a small head, a long stiff neck and a smooth and unarmoured skin. This skeleton of *Cryptocleidus oxoniensis* was found at Peterborough and is about 11 feet long. In the reconstruction (*top*), the Plesiosaurus is diving after fish

eighty-four feet in length and nearly thirteen feet in height, measured at the hind limbs. But vaster still was the Atlantosaurus, a somewhat similar creature, whose remains have been disinterred from the Jurassic formations of Wyoming, U.S.A. It was probably 100 feet in length, while its thigh-bone alone—a cast of which can be seen in the Natural History Museum—was six feet long and of enormous strength, hinting at the colossal weight which it had to support in life.

Strange and Fantastic Dinosaurs

Not all of the great dinosaurs went upon their four legs, and not all of them by any means were herbivorous and inoffensive. There were fierce and terrible lizard-like dinosaurs that walked and ran habitually on their great hind legs, supporting themselves with their long and heavy tails, like the kangaroos and wallabies, and touching the ground only occasionally with their comparatively small forefeet—this much has been deduced from the fossilized footprints which these creatures left in the once-wet sand. Among dinosaurs of this type were many that were very powerful and agile, with numerous long and sharp teeth and equally sharp claws; and these must have preyed cruelly upon their mild and unwieldy herbivorous brothers. Such was the Megalosaurus, a European dinosaur about twenty feet in length, with great tiger-like fangs in its powerful jaws; such also was the Ceratosaurus, one of the terrors of North America at this remote period, which, in addition to its sabre teeth, had a large and formidable horn upon its head.

Perhaps the most fantastic of all these nightmarish reptiles were the Jurassic dinosaur known as Stegosaurus and its several related species. Stegosaurus was fully as big in the body as a large elephant, and must have weighed many tons. Its hind legs were twice as tall as a well-grown man, but its forelegs were short in comparison, so that the creature's relatively small head, with its parrot-like beak, was carried not very far above the ground. The long and heavy tail bore a double row of long, sharp spikes, constituting a weapon with the most deadly possibilities; but perhaps the most remarkable feature of Stegosaurus was the double crest of great, roughly triangular, upright bony plates which were attached to the top of its back, from head to tail.

As though not content with being the unquestioned lords of land and sea, the reptile creation had already invaded the air in Jurassic times; and curious, bat-like winged lizards (pterosaurs) flew over the fantastic scene, seizing beetles, cockroaches and crickets in their sharp teeth. There were neither birds nor bats when the pterosaurs came into being, but these uncouth winged lizards resembled a blending of the two, though unrelated to either; and they are such highly specialized creatures that an enormous span of time must have been necessary to bring about their evolution from ground reptiles. Unfortunately, as is her wont, Nature has here left us a record only of her finished product and there is no trace of its intermediate evolutionary forms.

Each of the long, skinny wings of the pterosaur was supported by one of its immensely elongated fingers, and was attached behind to the hind limbs and tail. The latter organ was sometimes quite short, as in the Pterodactyl, a creature ranging through various sizes, from that of a sparrow upwards; but there were also pterosaurs with immensely long tails which must have trailed far behind them in flight and which sometimes terminated in a curious flap of skin like a rudder.

Beginnings of Bird Life

Being reptiles, the pterosaurs were, of course, quite destitute of anything like feathers or fur to cover their naked skin; yet in the latter part of the Jurassic period there were weird feathered creatures flying about that cannot be regarded as otherwise than true birds, though the earliest and crudest of feathered being of which man has any knowledge. The first fossilized specimen of these primitive birds—Archæopteryx it has been christened—was discovered in Bavaria in 1861 and is now in the Natural History Museum, London; its great importance was recognized at once, for it constitutes a link between all the birds as we know them to-day and the ancient land reptiles from which the whole avian class evolved. For once, Nature has taken us behind the scenes of her theatre of mysteries, and shown us an entirely new class of animals in the making, though already at a stage of very high development.

Archæopteryx was about the size of a rook or a pigeon; in place of the horny beak of existing birds, it had a blunt jaw set with sharp teeth (which no modern bird ever has), and its fore-limbs terminated in three distinct clawed fingers, which in later birds fused together, and became functionless as digits.

The most remarkable feature of Archæopteryx was, however, its extremely long, slender, bony tail, quite unlike that of any recent bird but closely resembling the tail of a lizard, though set with two rows of true feathers.

In the seas of the Jurassic period fish were beginning to approach their modern forms, and ganoids were degenerating. The great aquatic reptiles which we have met already were abundant, and so were the crocodiles and alligators and the earlier forms of our soft-skeletoned sharks and sturgeon. Cuttlefish appeared for the first time, while their allies, the belemnites, have left their horny internal skeletons in large numbers in the deposits of this age, much to the perplexity of the uninformed when they find them in cliffs and cuttings. Other cephalopods that were particularly active during this period and the next were the ammonites, with their chambered shells resembling those of the modern nautilus. Ammonite shells display an infinite variety of form and size, some being quite straight and tube-like, while others are coiled, loosely or tightly, into a spiral; some species are very minute, while others, of the spiral kind, may measure as much as five feet in diameter. They are often popularly misidentified as "petrified snakes."

Plant life was still of a simple, archaic order in Jurassic times: ferns and horsetails still held their dominant position, together with the palm-like Cycads, which had arisen during the previous era. There were yet no flowering plants, though coniferous trees had made a great advance, and there were forms little different from our cypresses, yews and pines. The slender insect population was enriched by the first flies and ants.

Gigantic Reptiles of the Chalk Age

The great Mesozoic era ends with the Cretaceous period, which witnessed the last stand of the giant reptiles, a race which was to disappear from the face of the earth in the beginning of the next geological era. However, in the Cretaceous there flourished some of the most grotesque and fearsome dinosaurs of all. There was the terrible Tyrannosaurus, for example, the largest of the carnivorous dinosaurs, which stood twenty feet high. It ran and walked habitually on its great hind legs, balancing itself by means of its heavy tail; its skull alone was more than a yard in length, and it had teeth like those of a tiger. It must have been an appallingly fierce and agile creature, striking terror into all weaker animals.

Then there was the thirty-foot monster known as Triceratops, which had very much the appearance of a large rhinoceros, though with a long, trailing tail, a bony frill covering its thick neck like a great piece of armour, a horn projecting forward on the tip of its nose, and a pair of long, sharp horns above its eyes. The skull of this dinosaur, with the bony neck-piece attached, measured sometimes about six feet in length. Truly a formidable beast!

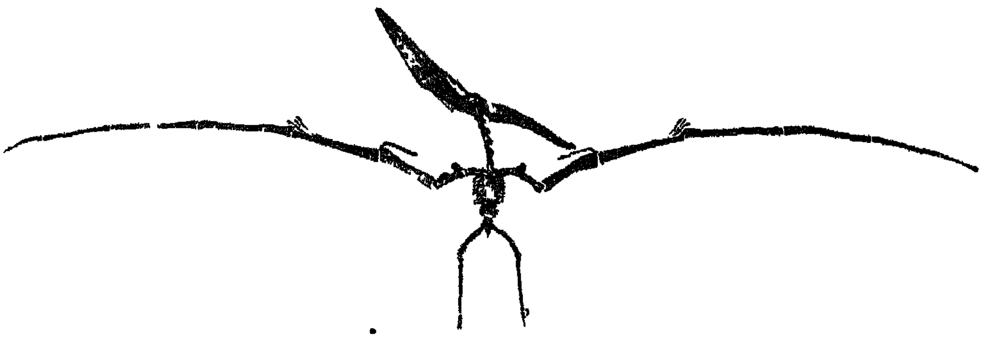
Another fantastic creature was the Trachodon, a swamp-frequenting dinosaur that went upon its hind legs like Tyrannosaurus; it was notable for its broad, flat, spatulate beak, like the bill of a duck.

The Iguanodon in Kent and Sussex

Over the weald of Kent and Sussex roamed the great herbivorous Iguanodon, the fossilized bones of which were among the first dinosaur remains known to scientific men. The Iguanodon also stood in a kangaroo-like posture, and even when walking or running it touched the ground only occasionally with its forefeet, as we can see from its fossilized footprints. It stood about fourteen feet in height, while its skull—no less than a yard long—had powerful, toothed jaws terminating in a hard, horny beak, like that of a turtle. Yet this dinosaur was probably a very inoffensive kind of creature and, no doubt, since it had no bony armour, was preyed upon cruelly by more bloodthirsty reptiles. It probably frequented swamps and marshes, where it could escape its enemies by plunging in the water, for it seems to have been able to swim powerfully by means of its enormous tail.

Remains of Iguanodon have been found near Hastings and Maidstone and in other parts of England, but the most remarkable discovery was made in Belgium about 1877, when no fewer than twenty-two skeletons of these huge lizards were found in a coal-mine; a number of them have been mounted in the Brussels Museum, where they form a most impressive spectacle.

Pterosaurs, the winged lizards of the air, attained their greatest development in Cretaceous days, and at the same time some of them lost their teeth. Of the latter kind was the creature known as Pteranodon, which measured eighteen feet across the wings, and there were other species nearly half as big again. The skull of Pteranodon alone was nearly four feet in length, and

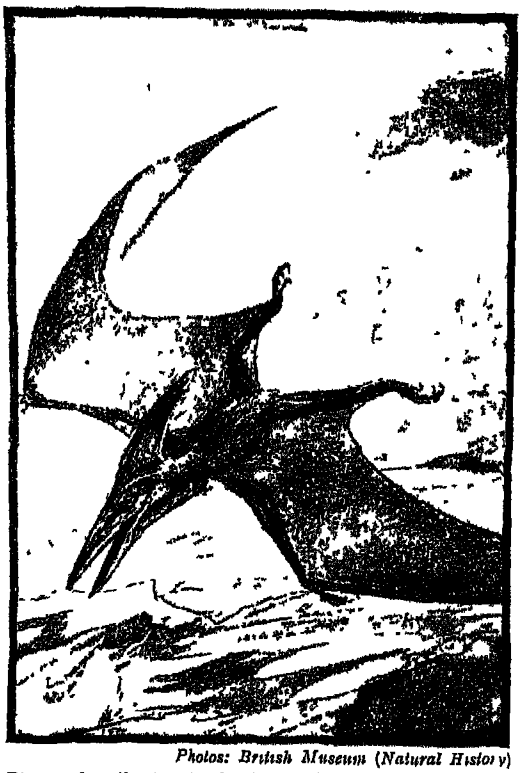


though devoid of teeth, it had a long, pointed beak of immense power. But some of the largest pterosaurs had a full set of teeth, and they must have been weird and wonderful creatures indeed

There were animals no less remarkable in the Cretaceous seas. Apart from a whole world of small life—sponges, corals, cephalopods, shellfish and so on—there flourished predaceous ichthyosaurs and the largest plesiosaurs of all, while new tyrants had come on the scene in the form of toothed serpents of prodigious size, known as Pythonomorphs, whose snake-like bodies were impelled swiftly through the water by means of powerful paddles; some of these dreadful beasts reached a length of seventy-five feet.

True birds (some of them flightless and all of them toothed) and bony fishes were becoming common in Cretaceous times, while the plant life was growing quite like that of to-day. Oak, elm, walnut, fig and others of our modern trees mingled their foliage with that of the vastly older ferns and conifers, and the Cretaceous period witnessed the first flowering plants.

The great Mesozoic era had now come to end; it had produced, in the dinosaurian reptiles, the most remarkable race of creatures that has ever existed, but a race that was fated to perish entirely as the epoch came to a close. In the opinion of most zoologists, their extinction was due to the fact that the size and power of their brain were woefully low in proportion to the vast bulk which they had to maintain. The great armoured Triceratops, for example, had a brain that in proportion to bulk of body was only one-tenth the size of that of a crocodile. The Brontosaurus, fifty or sixty feet in length and of prodigious bulk, had proportionately the smallest brain of any vertebrate animal. The Diplodocus, more than eighty feet in length, had to do all its thinking with a brain the size of a walnut. Even in those



Photos: British Museum (Natural History)

Pteranodon, the great flying lizard of the Cretaceous period, had a wing-span of 18 feet and probably flew like an albatross—by gliding and soaring on air-currents. *Pteranodon occidentalis* fished in the chalk seas of Kansas, U.S.A., where the skeleton (*top*) was discovered

dinosaurs that had tremendous skulls, but a mere fraction of the space was occupied by brain. So, unable to adapt themselves to changing conditions, the great reptiles declined; other creatures with larger brains and more alert faculties outdid them in the

struggle for existence, and when we come to the next period, the Eocene, with which the Tertiary or Kainozoic era begins, the curtain goes up on these creatures—the mammals—already large, well developed and active, although even the latest Jurassic records had shown them as small, primitive and unimportant. Clearly there must have been an enormous interval between Jurassic and Cretaceous days, of which but scanty evidence has been left in the rocks.

The Tertiary era, that consists of the Eocene, Oligocene, Miocene and Pliocene periods—each of which covers a vast span of time—is primarily the age of mammals, an age in which this great class of living creatures rose to the supremacy which they still hold; and yet not all the living species that evolved have survived until modern times. This, indeed, is just as well, for in size and ferocity some of those departed mammals vied almost with the dinosaurs they had replaced. There were, for example, the creatures known as Dinocerata (plural of Dinoceras), whose remains have been found in the Eocene of Wyoming. These were heavily-built, four-footed beasts, with a remarkable resemblance to a rhinoceros, yet with as many as three pairs of horns on their ungainly heads, and sometimes with two enormous curved teeth projecting from the upper jaw; these animals were nearly as large as elephants, standing about seven feet or eight feet high at the shoulder.

The Ancestor of the Rhinoceros

Huge beasts also were the Titanotherium and its congeners. It was a sort of ancestral form of rhinoceros, and grew to a length of fourteen feet, but its horns were set one on either side of its nose, instead of in the middle line of the head, as is the case with modern rhinos, and it must have had a more ferocious aspect than has any animal of to-day.

Co-existent with these creatures were the very early mastodons, ancestors of the elephant tribe, with their freakish forms of tusk development and their persevering experiments towards the evolution of a proboscis; we have already glanced at some of these animals in the earlier part of this chapter. The ancestors of the horse, too, roamed over the plains in the Eocene and succeeding eras, but they were small, timid, three- and four-toed animals, with only the remotest resemblance to the noble, single-toed friend of man.

Meanwhile, all kinds of carnivorous mammals were evolving, many of them being of considerable size; though, as has always been the case, they were not so big as the larger ruminants. They had the form of ancestral pigs, wolves, rats, hyænas, great

Photos: British Museum (Natural History)

Leaves from the forests of the Tertiary era. In the Eocene, or first part of this period, the south of England enjoyed a sub-tropical climate, and such trees as fan and feather-palms flourished. This portion of a feather-palm leaf (*top*) is 4 ft. long and was found at Bournemouth. From a later and cooler time—the Miocene—comes the delicate leaf of the Poplar (*Populus latior*) which was unearthed at Oeningen, near Lake Constance in Switzerland, and is here shown about half natural size

cats with sabre-like teeth, while many of them had characteristics that seem to show a connexion with the pouched mammals of Australia. The latter important group, by the way, seems to have produced its largest form in the Pleistocene period, which followed the Pliocene; this was the monstrous wombat known as Diprotodon, the size of a large rhinoceros, whose huge skull was provided with gnawing front teeth resembling powerful chisels. The spectacle of this formidable beast carrying its young in its pouch must have been a curious one, to say the least.

Photo British Museum (Natural History)

Monster ancestor of the clumsy sloth of South American forests—*Megatherium americanum*, which instead of climbing trees like its small descendant appears to have pulled them down

While the monstrous beasts we have described were slowly evolving, attaining their racial prime and becoming extinct or else approaching more and more towards the forms assumed by their recent descendants, we must imagine innumerable other creatures—and plants as well—developing with them side by side, forming a background to the scene over which marched these uncouth giants, lords of creation. Whales, seals and true fishes in abundance swam in the seas, together with sharks 100 feet in length. Birds, too, were prominent; eagles, buzzards, owls, herons, gulls and plovers—these or their ancestral types were but a few of the Kainozoic denizens of the air. But there were other birds with undeveloped wings that could not take to the air, and were obliged to run about the ground like the modern ostrich and emu. One of the most remarkable birds of this type lived in Patagonia. It was the crane-like bird known as Phororhacus, which stood twelve feet or so in height, and had a monstrous hooked beak of tremendous power. In strength and ferocity it must have far outrivalled the largest eagle, and indeed it comes nearer to the fantastic roc of eastern legend.

Dawn of the Pleistocene Era

So we arrive at the Pleistocene era—the fourth, or quaternary, great age in the geological history of the world—in which the face of the earth came to have much the same appearance that it wears to-day and in which Man, the most triumphant manifestation of the large and complex mammalian brain, was to begin his sensational and comparatively brief rise to world dominance.

Nature had still some huge and amazing creatures to produce; and for some of the strangest forms she seemed to regard the South American continent as particularly favourable. There was the so-called Toxodon, for example, whose head Charles Darwin obtained at La Plata for the value of eighteenpence. It was a great hoofed quadruped, as large as a rhinoceros, yet in anatomical structure, especially in its huge chisel-like teeth, having much in common with the rodents, such as rats and guinea-pigs—if we can imagine a guinea-pig nine feet in length.

Then there was the Glyptodon, a progenitor of the armadillos of to-day. The latter are

small and inoffensive beasts inhabiting the woods and pampas of South America; they have a covering of bony armour fitting together with loose joints so that the armadillo can roll itself up in a ball like a hedgehog or a wood-louse. But the Glyptodon's body armour was in a single piece forming a continuous, rigid shield, six or eight feet in length, like the carapace of a tortoise. He had a hard plate, too, on the top of his head, and his short, thick tail was covered with overlapping bony rings and formed a weapon that, no doubt, could deliver tremendous blows. The whole animal was probably far more bulky than a large ox, and we can feel very thankful that its modern descendants have degenerated in size and strength.

Sloths are among the animals most characteristic of the South American jungles, where they can often be seen hanging upside-down in the tree-tops and climbing cautiously from bough to bough; in fact, they are almost exclusively arboreal animals, and are nearly helpless when placed on *terra firma.* In build, they resemble a medium-sized dog. But they had an ancestor of the Pleistocene age that rivalled an elephant in bulk. This giant sloth is known as the Megatherium. When erect, it had a stature of fourteen feet or so, and its ungainly body was covered with long, coarse, shaggy hair. From head to tail it measured about eighteen feet, and it must have weighed several tons, so that an arboreal life was denied to it and it was restricted to the ground.

Like its modern descendants, the Megatherium fed on the leaves and shoots of trees, rearing itself up on its hind legs and bending down the lower branches of the trees with its powerful fore-paws, and then stripping off the foliage with its long, prehensile tongue.

A Tantalizing Mystery of Zoology

Megatherium had a near relative—also a giant ground-sloth—called the Mylodon; and in dealing with this animal we touch upon one of the most tantalizing and romantic mysteries of zoology. In the year 1897 the attention of the scientific world was drawn to a remote and almost inaccessible cave, high up above the ravine of Ultima Speranza in southern Patagonia, near the Chilean coast, where undoubted remains of a Mylodon, as well as of several other animals, had been discovered. Strangely enough, in view of the many, many thousands of years ago that the Mylodon was believed to have become extinct, the remains bore all the appearance

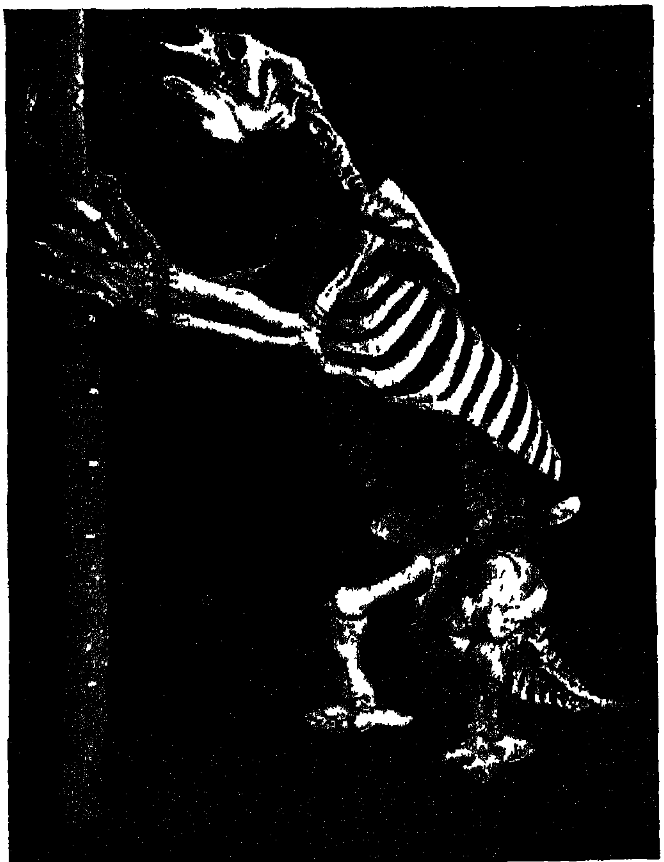


Photo: British Museum (Natural History)

Twelve-foot-high skeleton of the giant ground sloth (*Megatherium americanum*) the ungainly body of which was covered with coarse, lank hair

of having belonged to an animal that had lived in comparatively recent times. There were large fragments of dried skin, covered with shaggy hair; there were innumerable bones, some of them smeared with blood and bearing the dried remnants of tendon and cartilage; and there were the droppings of these huge animals in plenty. Moreover, there was a quantity of chopped hay, which seemed to have been stored in the cave for fodder, while several other traces of human occupancy were detected, such as stone

implements, remains of fires, and bones of man himself. The Mylodon was certainly contemporary with Man; but was this great beast alive in recent times, as the fresh condition of the remains would seem to suggest? The question is a very puzzling one indeed.

Man, the Conqueror, Appears

It was probably during the Pleistocene era—perhaps some half a million years ago—that Man began to be differentiated gradually from the ape-like creatures with which he shared a common descent. How and why he became differentiated is not clearly understood, but it was due most probably to some superior advantages—trifling to begin with—of hand and brain. So Man began his arduous ascent, which we cannot trace here in detail. He had many formidable enemies to harass him and to contest his very existence, though doubtless the incessant conflict did much to mould his mind and character and to shape his incipient culture. There was, first, the bitter cold of the Ice Age which, in one great wave after another, swept from the North Pole over Europe and North America, transforming the face of the land under the pressure of a vast cap of ice, obliterating plains and forests, and driving man and beast ever farther south.

Courtesy of the Southern Rhodesian Government

The art of primitive man has never been surpassed in its rare simplicity and fineness of perception. It was, moreover, the final indication that Man had become Man and had left the animals behind him for ever. This remarkable and characteristic example of early Bushman painting is from the Matopos in South Africa

Then there were the great beasts themselves with which early man was in constant warfare, fighting for a meal or for his life. There was the sabre-toothed tiger, with terrible canine teeth eight or nine inches in length, with which this beast slashed and poniarded its prey to death, for these teeth were far too large to be used in the ordinary way. There was the ponderous cave-bear, larger and more powerful than the modern Polar bear, whose bones are found in caverns in England mingled with those of man. There were colossal wild oxen, whose horns measured as much as eight feet from tip to tip, and which survived late enough to be mentioned by Julius Cæsar, who described them as being nearly as large as elephants.

There was the hairy mammoth, which bravely roamed the wastes of snow and ice; and there was the woolly rhinoceros which, with the mammoth, was one of the earlier inhabitants of that region which is now London. At this time, too, there flourished the largest and most lordly of all the deer tribe, the so-called Irish elk, which ranged over a great part of Europe, although its remains are most frequently found in the peat bogs of Ireland. Resembling probably, a gigantic fallow deer, it stood about six feet high at the shoulder, while its noble, branching antlers had in many cases a span of eleven feet.

There is reason for thinking that this splendid creature did not become extinct until nearly historic times, though there were many other creatures that went out of existence much later still; we may instance the quagga, the dodo, the great auk and—most remarkable of all—the giant moa of New Zealand. This was a running bird somewhat resembling an ostrich, but considerably larger. It had immensely stout and powerful legs and must have been able to proceed at a great rate, but its wings were almost non-existent and it could not fly. It carried its absurdly diminutive head at a height of twelve feet or more above the ground, and its colossal proportions must have greatly astonished the Maoris who first colonized New Zealand some five or six

hundred years ago. But, much to the lasting regret of zoologists, it was not long before the new arrivals had hunted the giant moa out of existence.

Our early human ancestors must have taken many, many thousands of years to pass out of the purely animal stage of their development, and even when they had the beginnings of an organized civilization, a great part of their behaviour and their way of thought must have been almost entirely animal. In all probability they had a bond of sympathy with the brute creation, from which they had not so long ago been differentiated, that is unknown to even the most primitive races of to-day. The habits and all the actions of animals were known to them intimately; and, probably for purposes of magic or ritual, they carved and painted upon the walls of their caves, on bones and antlers, representations of the animals of their day that are among the greatest masterpieces of ancient art. Mammoth, bison, boar, chamois and reindeer have been depicted for us with masterly simplicity, sometimes in the gloomy depths of unlighted caves, by the hands of a savage race who lived probably 50,000 years or so ago, who had never seen a piece of metal and knew none of the refinements of life, and yet had the exquisite perception of the true artist and a technique that could scarcely have been improved.

Though much has been written regarding the artistic qualities of these cave paintings of France and Spain, which we describe in another chapter, and of the no less remarkable work of the ancient Bushmen tribes of Africa, it is impossible to exaggerate the important part which these productions have in the story of humanity. For they illustrate the greatest triumph of the growing mind of man—the development of that conception of truth and beauty that was to lift the human race for ever above that realm of animal life in which its infancy had been passed.

CHAPTER XXVI

ELECTRICITY—THE POWER OF THE FUTURE

THE human race is engaged in a continuous struggle to secure greater control over its environment. It seeks to accomplish necessary tasks more easily, more pleasantly and more rapidly, whilst at the same time striving to discover more satisfying means of utilizing natural resources to that end. The thoughts that prompted the story of Aladdin and his lamp, doubtless arose from these strivings and their frustration. Often, however, the realization of an ideal, or a dream, does not come about until after its author has passed into the unknown, for progress that is lasting and real cannot come in a flash: it is the work of time and the painstaking task of many.

To-day, if the originator of Aladdin could visit us, he would see the astonishing realization of his dream. At the turn of a switch may flash forth light, of any colour to choice; heat may be compelled to radiate, or coldness can be produced. A genie, with the speed of light, flashes to the command of he who but closes a switch, giving just sufficient for the task at hand; never varying appreciably; instantly available, but never moving until the switch is closed; upon which, however, at a speed of 300,000,000 metres a second, the genie rushes to perform its duty—colourless, invisible, odourless, imponderable. But our modern Aladdin, the blasé closer of switches, pays little heed to the wonders of the service he thus secures from his ideal servant—Electricity.

What Electricity is and How it Works

Whilst it is not within the scope of this chapter to enter into deep technicalities, it is possible to discuss in a simple fashion the fundamentals underlying the nature of electricity and how it performs its service, and so to enable an enthralling mental picture to be presented that will enable subsequent processes better to be understood.

Sufficient is now known about the constitution of matter to enable us to say that matter of any form—i.e. solid, liquid or gaseous—has a common basis. In all the elements that have been so closely examined it has been found possible to observe a basic principle of construction. All elements are, in fact, merely different formations of the same basic arrangement. For example, the difference between iron, copper or hydrogen is merely one of varying formation of the basic constituent—electricity, that can neither be seen, smelt nor collected as a ponderable substance.

The common property thus possessed by all elements is that of giving up, when suitably agitated electrically, definite quantities of electric charge. The difference between one element and another lies in the quantity of electric force that is bound up in each atom The most wonderful aspect of this question is that electricity itself is the only possible medium by which its own mechanism may be thoroughly examined; the secrets of Nature are most completely revealed when suitable electrical forces are applied.

By the aid of electricity the transmutation of matter has been accomplished, thus proving that the alchemists' idea that lead could be turned into gold was not an impossibility, even though they themselves were unable to accomplish it by direct chemical reactions. By applying sufficient electric force, it is possible to remove a portion of the electric charge on an atom of a substance and thus bring about its transmutation. For example, from lithium has been produced helium; sodium iodide has become helium and neon, and hydrogen has been produced from potassium, whilst radium and thorium transmute naturally.

Mysteries of the Atom

Many of the discoveries of the nature of matter have become cloaked behind a host of technical phrases and names, some of which completely hide actual mechanisms. Thus, the definite quantities of electric charge that can be forced from an atom have been named, just as if they were of material substance like a piece of coal.

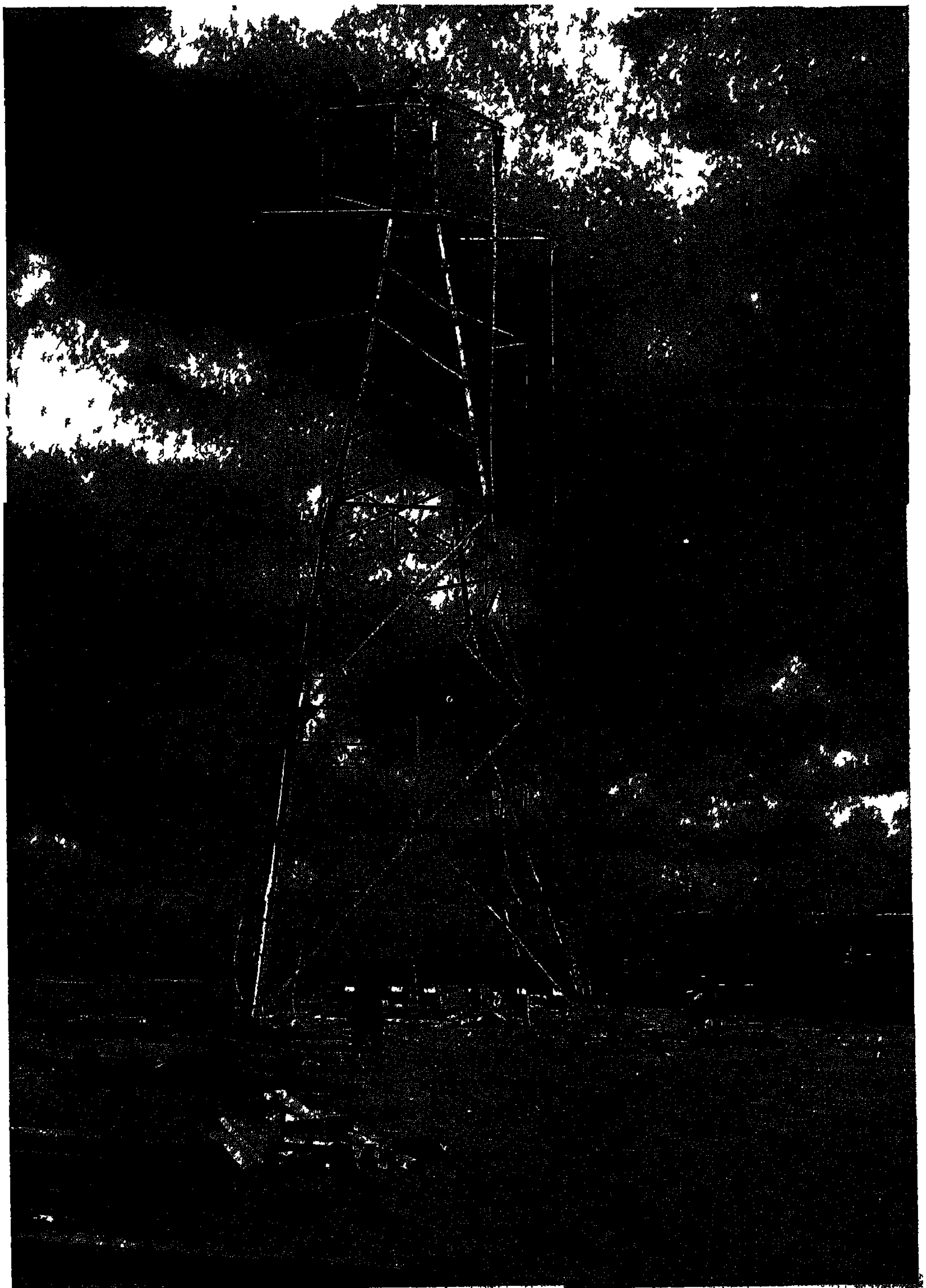
The name given to the indivisible quantity of electric charge, associated in different formations and amount with different atoms, is the electron—the unit quantity of what is usually known as negative electricity. Normally, these electrons revolve round a central position or region of positive electric charge and the whole constitutes an atom, whose nature depends upon the number of electrons and their disposition with respect to the central equal and opposite charge; the latter is always equal to the electronic effect, and keeps the system stable in the absence of the influence exerted by electric charges. The whole system is balanced, like that planetary system of which the earth is a relatively small part. An atom is, in effect, such a system in microscopic form. The difference between, say, iron and hydrogen is merely in the disposition and quantity of the units of electric charges associated together in the formation which we now call the atom—i.e. the smallest portion of any substance that can be isolated, or that is not capable of further division without losing its existing character. If some part of these charges be expelled from a given atom, say iron, it ceases to be iron and assumes another character, according to the amount thus released. Only by means of electric forces can this transmutation of elements be successfully undertaken, so that we have the wonderful spectacle of electricity acting upon itself to reveal its own secrets.

Magic of the Electron

In common parlance, the word electricity is applied to the movement of electric charges—of electrons, in fact. It is impossible to see this movement and we judge of its capabilities, therefore, by observing the effects it produces. We may measure an electric current by observing the quantity of heat, light or mechanical force it produces. The quantitative control of electricity can be made so wonderfully fine that it has been found possible to measure exactly the effect produced by the change of position of one electron—i.e. a unit charge. Its mass is one eighteen-hundredth part of the mass of an hydrogen atom, which is the lightest known element. The charge the electron carries is one six-trillionth of a coulomb, the latter being the quantity of electricity moved when a current of one ampere flows for one second. Accordingly, if one electron alone continued to move in a conductor for one second, the current produced would be one six-trillionth of an ampere; the ampere is the practical unit of current flow used in everyday life.

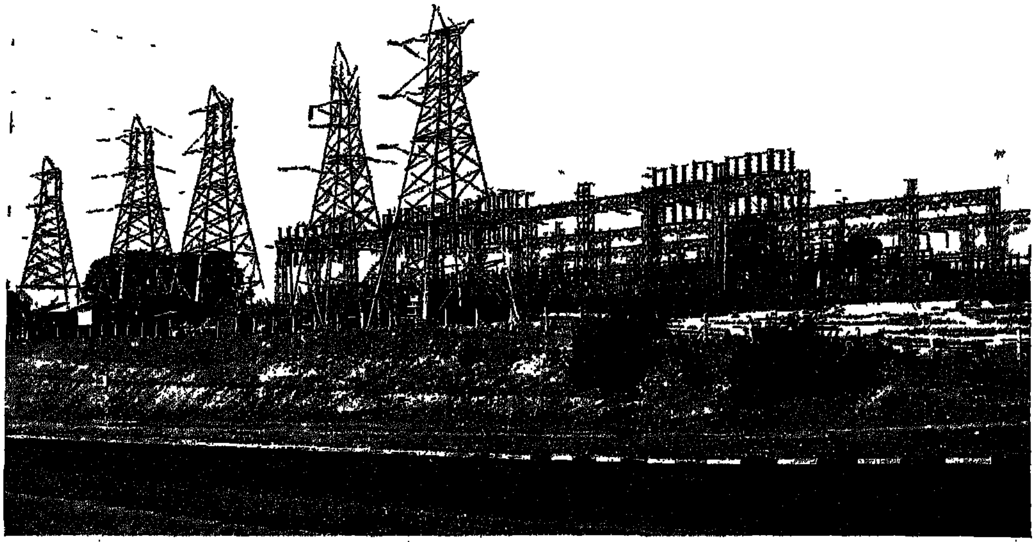
Owing to the fact that our everyday requirements of electricity are so great, the basis upon which we measure it is tremendously greater than the small values quoted above for solitary electron charges and movement. We measure movement of electric charges by units called amperes and call it current flow—although the idea of electrons flowing along a wire like peas in a pipe is scarcely accurate. If one ampere passes for one second, unit current flow is registered. The pressure change between one end of a conductor and another as a result of that current flow is measured in volts, and the energy expended when electricity moves is measured by the multiple of volts and amperes, the resulting units being called watts.

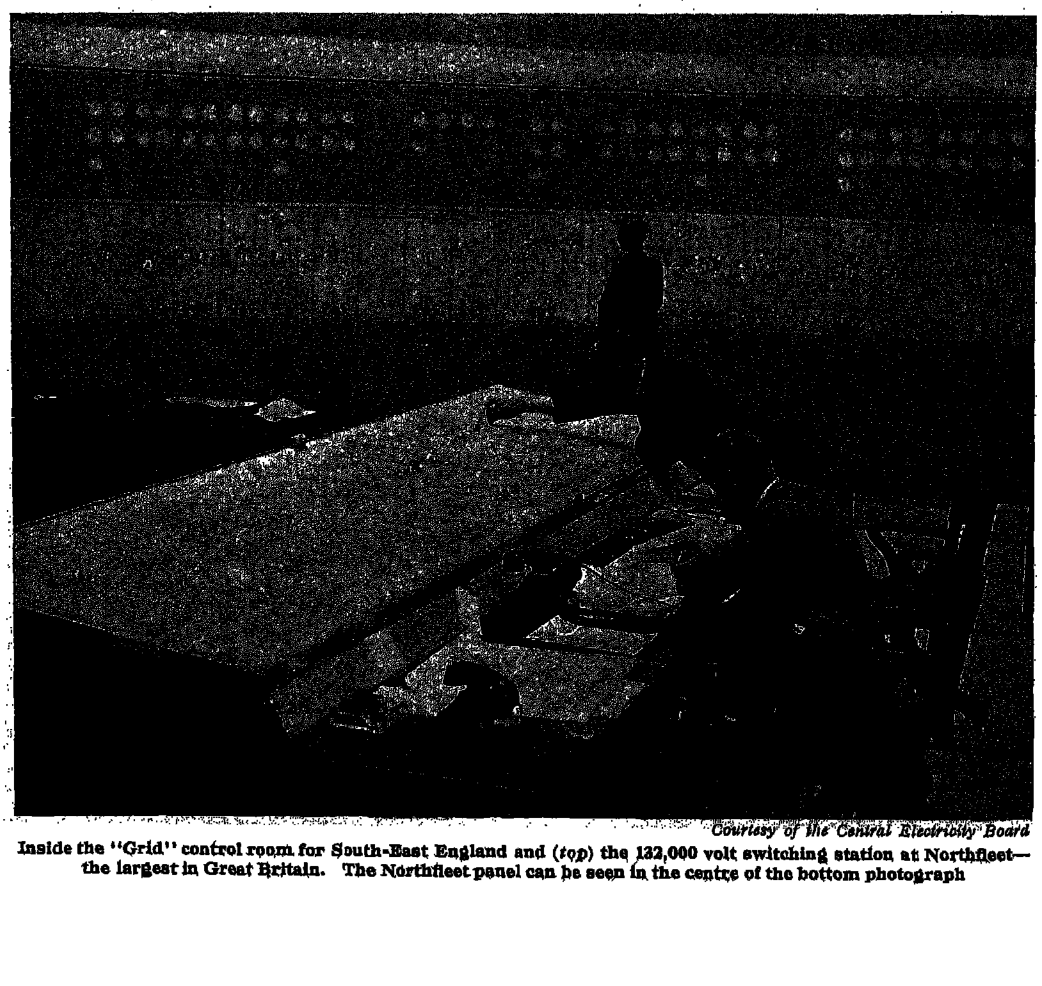
It is for watts that users of electrical



Courtesy of the Central Electricity Board

Now a familiar sight throughout Great Britain and the best known visible evidence of the Electrical Age to come [illegible] lofty steel pylon. Men are here seen stringing the insulators on a "Grid" line





Courtesy of the Central Electricity Board

Inside the "Grid" control room for South-East England and (*top*) the 132,000 volt switching station at Northfleet—the largest in Great Britain. The Northfleet panel can be seen in the centre of the bottom photograph

Courtesy of the Central Electricity Board

Carrying the power across the countryside—rural distribution lines in the Clyde Valley. Power lines have to be constructed to withstand all weather conditions

energy pay. The well-known "unit" that figures in the accounts sent to the consumer by the supply company represents the electrical energy involved by the consumption of 1,000 watts for one hour and is known technically as a kilowatt-hour or, shortly, 1 *Kwh.* This is the Board of Trade unit.

Power over Hill and Dale

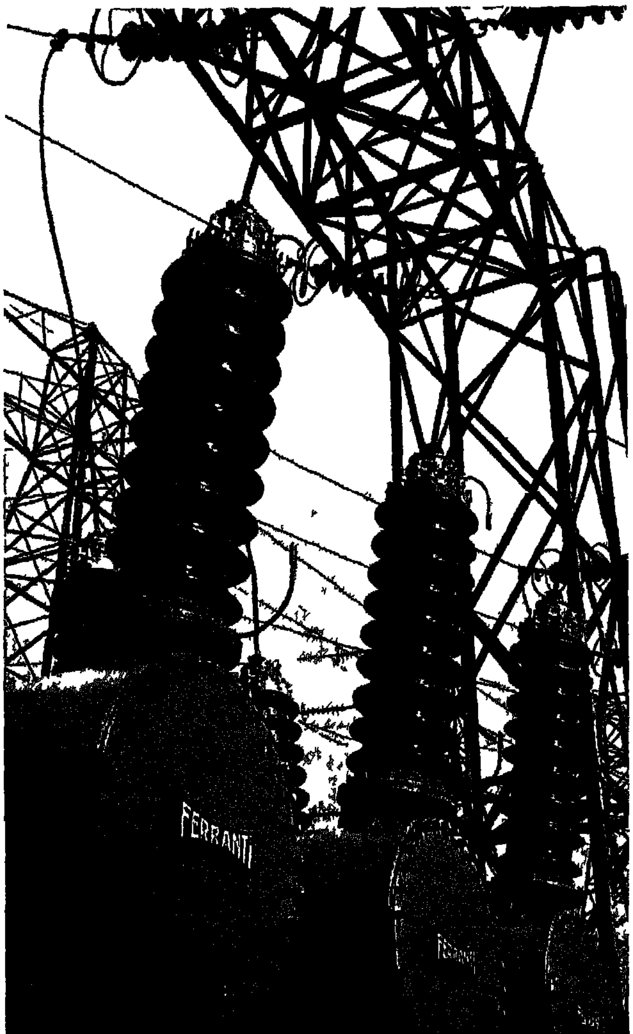
The immense extent to which electricity is now utilized has brought into being the accomplishment of vast schemes for generation and distribution. Huge power stations such as those at the Boulder Dam, Colorado, Niagara; Barking, London; or the great hydro-electric ones in Russia, have taken the place of more numerous but smaller stations supplying the needs of a local area. So great has become the demand for electrical services that the stations of yesterday find themselves unable to cope with it.

All over the world the story is the same: there is an insatiable demand for electrical service. Gigantic in its day, the station at Niagara Falls, where the inexhaustible resources of the world-famous waterfall are tapped, pales before the stupendous engineering feat lately completed at the Boulder Dam, Colorado (*see illustrations* CHAPTERS XII and XXII). Here the Colorado River is being harnessed to drive such gigantic turbine generators that their initial power will be 2,000,000 horse-power—i e. roughly 1,500,000 kilowatts, which is four times the power generated at Niagara.

In this Colorado scheme, the water in the turbine tunnels falls nearly 475 feet When it reaches the turbines, it has a speed of 120 miles an hour. The enormous amount of water may be appreciated from the fact that it passes through eight gates or valves, each of which is thirty-two feet in diameter and has a total weight of 2,000 tons.

In England our own vast and smoothly running electricity supply service operates on somewhat different lines, under the

guidance of the Central Electricity Board. Here as many as 135 selected stations are being linked up all over the country for the purpose of supplying a nation-wide electrical network. The idea of a single huge station has been ruled out on various grounds, and the Board have relied upon the effective linkage of a number of stations throughout the country. A complete disconnection of supply for any extended period is virtually impossible, and when the Board have finished their work, failure will be exceedingly remote, owing to the system of interlinkage and the provision of carefully placed spare plant.



Courtesy of the Central Electricity Board

Protecting the power lines against sudden surges in supply. Surge absorbers at a "Grid" transforming station

The cost of this electricity scheme has been £26,500,000 sterling; there are 4,000 miles of transmission lines stretching over hill and dale, three-quarters of which carry the supply at the high "pressure" of 132,000 volts, while the others are at pressures of 66,000 or 32,000 volts respectively.

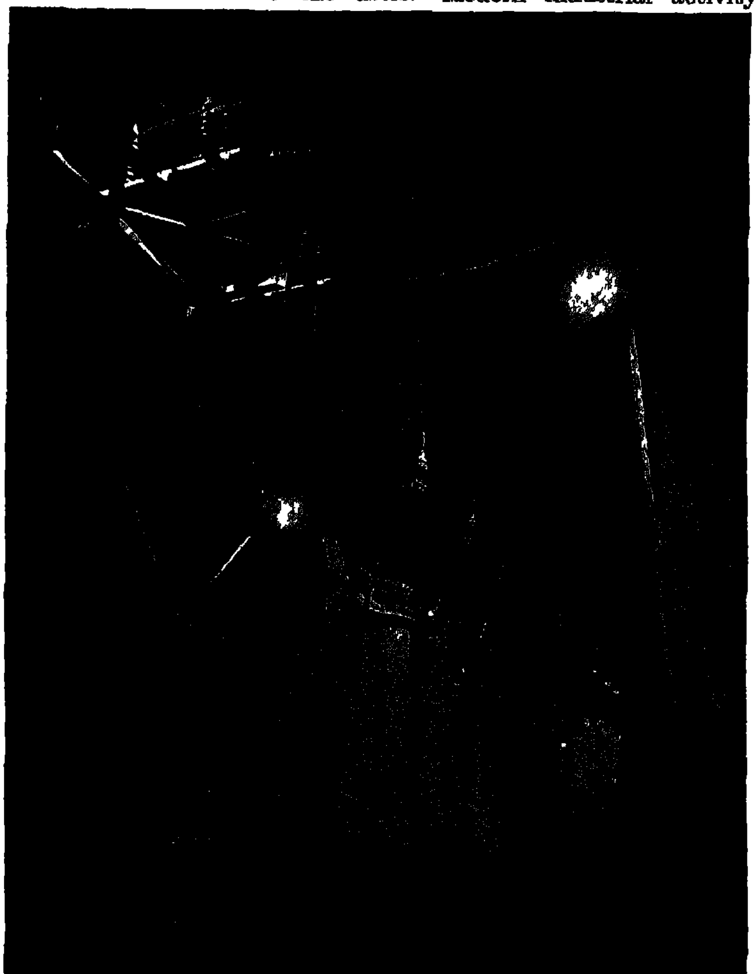
Most of the problems attending the generating of electricity in large bulk have been settled for a considerable time; it was the question of effectively distributing this generated energy that caused most difficulty. In the ordinary way it is impossible to transmit electricity at safe working voltages to consumers over long distances, exceeding a few miles, because of losses due to the resistance of the conductors.

The solution of the problem was to generate the electrical energy at such high voltages that losses over the whole system became insignificant and formed a negligible part of the power available anywhere in the system. It is very difficult to convey "direct" current like this, and so alternating - current generators, yielding a pulsating current that periodically reverses its direction, are used almost exclusively for power transmission on the large electricity generating schemes of the world, including our own "Grid" scheme. Direct-current high-tension schemes do exist, but are in the minority.

The grid scheme transmits electricity at the high voltages previously mentioned—voltages that are transformed down by supply undertakings to household or industrial values of 230 volts, 400 volts, and in certain cases to somewhat higher voltages. Two methods of conveying electrical energy from power station to user exist: underground cabling or overhead transmission lines. In the working of a distribution scheme both have to be utilized; the former is essential in towns and thickly populated areas, but overhead lines are favoured for open country. To lay cables over hill and dale and under rivers is not a work to be undertaken lightly, owing to the vastly greater expense than that of a comparable overhead network. Accordingly, we now see large towers dotted over the countryside mostly with six wires apiece;

these lines carry the high-voltage electrical energy from one end of the land to the other.

In order to make this scheme possible, it was necessary for manufacturers to develop special insulators that would withstand the enormously high voltages between the transmission lines and would also resist the effect of the weather. The designers of towers also had to prepare for all weathers, allowing for the stresses due to varying expansion and contraction; the wire makers had to produce light-weight cables capable of carrying the current and able also to withstand wind pressures and swaying, in addition to tower spring. The lines had to be protected against sudden surges in supply and, worse still, against lightning, which may strike with a pressure of over 10,000,000 volts. Though it is not possible completely to protect overhead line systems against a direct stroke of this magnitude, failures of supply are exceedingly rare—a fact that speaks volumes for the organizers and builders of such a scheme. These transmission towers, and the power lines they support, thus symbolize the realization of a centuries-old dream of Mankind: to have at his disposal, by the mere movement of his hand, power to perform his every task.



Courtesy of the Australian National Travel Association

Electric power is being developed to a vast extent overseas and is the life-blood of thousands of great industrial and agricultural areas. A night view of the switch yard at the Yallourn power station, Victoria, Australia

Electricity in Industry and Commerce

Industry and commerce, depending for their successful operation upon the co-ordination of innumerable enterprises both great and small, have to rely upon effective communication between one and the other. Without electricity this co-ordination would be impossible, because by communication we mean not only the interchange of speech but the passing of raw materials from one region to another, of products from one section of a factory to the next, the control of machinery during a whole series of operations, and the dispatch of finished goods to the users. Modern industrial activity could not conceivably go on if by some means electricity was denied to it; indeed, it is by virtue of electricity that such wonderful advances have been made in factory and commercial procedure.

No section of commercial activity is now left untouched by the benefits that electricity can bring to it. Labours have been lightened and tasks otherwise impossible are now performed with ease, whilst vast new avenues of approach have been opened up. In

some instances the advances have been phenomenal and we propose to refer here to some of the most remarkable of them.

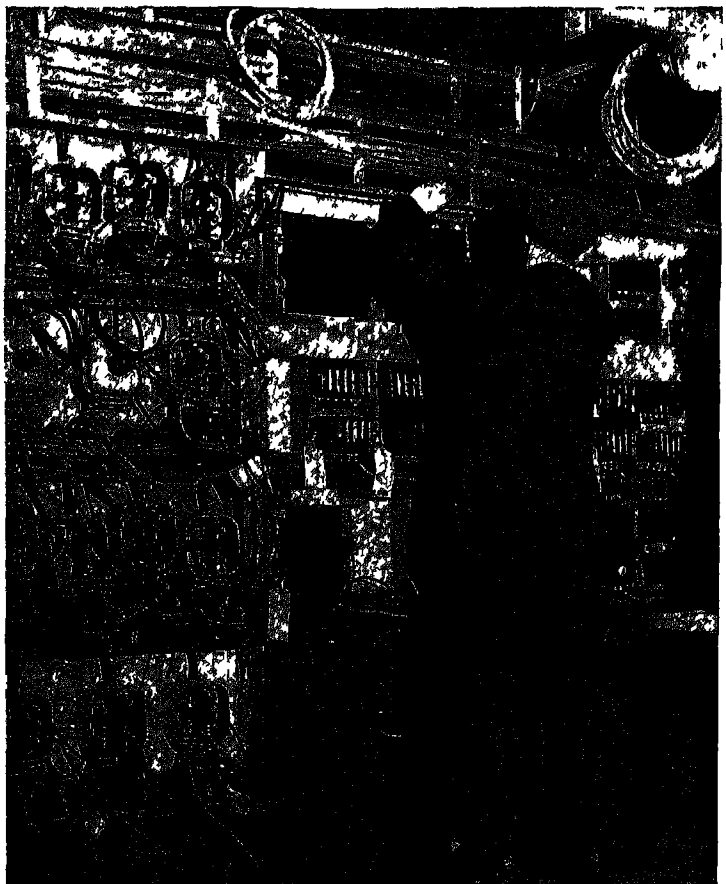
On the Ocean

Since our empire depends upon her shipping for her existence, we may well begin with that ancient enterprise. The sailing ship has been almost forgotten, except by the romanticists whose pleasure it is to dwell upon the past. The steamship provided a far more safe and reliable means of transport across the seas, and to-day we have the steam-electrical vessel. The dirty, smoky, inefficient stokeholds of bygone days are fast giving place to the clean, silent, oil-fired furnaces which provide the steam for driving the turbines; in the turbo-electric vessel the turbines give motion to those mighty generators whose energy drives powerful electric motors that propel the ship through the water.

Reliance has no longer to be placed upon the magnetic compass, with its errors and ever-changing deviations. Indeed, although such compasses are carried as stand-by apparatus, we now have the electrically-driven gyroscopic compass with its steadfast, undeviating North point, ever directed towards geographical north instead of magnetic north. Towards the latter the mariner has no real affinity since it is by the former that he sets his course.

Wireless Direction Finding

No longer also is the sailor dependent upon fine days and optical sextant readings for ascertaining his true position in the midst of oceans. Often were such readings in serious error, owing to weather conditions. Now, however, the wireless direction finding apparatus, in the space of a minute at most, can fix for the navigator his exact position. So, to-day, the electric ship sails the seas, a magnificent testimony to the value of electricity in industry and commerce.



Only a small part of the complicated electrical installation on a modern liner. Wiring up the switchboard in the main restaurant of the *Queen Mary*

Think of the drudgery of a few years ago, in the laborious handling and shaping of parts to compose a whole, that went on day after day in the average factory, while its organization slowly and painfully turned out the goods for sale. Then look at our modern, present-day counterparts of those once famous organizations.

Vast quantities of the hardest steel are melted in due season, at the touch of a switch on the electric furnace. The finest tempered steel slowly draws out of the never changing, wholly reliable annealing furnaces and goes to electrically-driven processes and other machines, some of which may cut through inches deep of the hardest metals, or shear off pieces as required. Yet electricity does not stop at exerting enough energy to operate these powerful machines. It can also protect them from breakdown. By means of a delicate photo-electric cell, passing but a minute current, when working, the

machines may be brought up abruptly and safely should the steel feeding through them become held up. In a flash, a minute impulse darts through the protective electrical relays and throws open the main switches in time to avert a catastrophe. A force equal to hundreds of tons of pressure to the square inch is arrested in a flash by electricity adequately controlled—which is but another of the marvels of our modern, invisible servant

Nor does electricity excel only in heavy work. For example, in the cigarette factory we can see finely-tuned machines that weigh to a fraction the tobacco for each cigarette of the millions made each day. Delicate relays and trip-switches stop and start the sequence of events. The cigarettes are weighed, rolled, gummed and counted into packets, by means of electricity. No human hand need touch them.

The Motor-car

Paradoxically enough, although the modern motor-car depends upon petrol for its actual propulsion, it could hardly be made to go at all without electricity. To realize this one has only to examine some of the early and non-electrical ignition devices. It is the tiny spark produced at the sparking plugs (from an induction coil fed by a battery, or from a magneto) that ignites the petrol vapour which, unless it *is* ignited, is powerless to produce any motive power. Nor would the motor-car be in such universal use but for the service that electricity gives in its manufacture.

Courtesy of the G P O.

The transmission of pictures over a great distance by land line and wireless has reached such a stage of perfection that there is now very little difference between a picture sent in this way and an ordinary *photograph.* Receiving *a picture at the office of the G.P.O. Picture* Telegraphy Service

Not everyone could afford to purchase or, indeed, to run the highly-expensive, almost perfect, mechanisms produced by hand fitting that are embodied in the best of our internal combustion engines. It is mainly electricity that has made mass production of motor-cars possible. Accordingly, we find, in the vast factories of Ford or Morris, a huge network of electrical machinery which produces parts of the car and then hurries them off forthwith to the next operation; there a further process, likewise controlled or performed by electricity, transforms these components into the desired form, and electrical machinery aids their assembly.

Owing to the fact that it is the commercial side of life that receives most public attention, any development therein is soon appraised for its true worth; whereas other processes, of far greater magnitude, go unmarked by the many. For instance, the wonderful process of securing copper or aluminium of practically one hundred per cent. purity by means of electrolysis, with currents of hundreds of thousands of amperes, is marked by the few; but the fact that a trunk call can now be put through from Britain to another country on the other side of the world, within say, half an hour, calls forth much comment.

Progress in commerce has depended for some time upon the parallel progress of electrical communication. From the time when the first telegraphic message was laboriously sent out and successfully received, a few miles away until to-day, the accuracy, and rapidity of communication have steadily progressed. The manual operator sending

in Morse code has given place to the automatic sender and receiver, whose rate of working is ten times that of the average manual operating speed. We now have the automatic sender giving place to the teleprinter, by means of which a typist at one end of a line, or wireless link, can type out the message that will thereby be immediately typed out by a similar machine at the other end.

Even the transatlantic cables are becoming too slow for the modern business man. He now calls up his telephone exchange and asks for the number he requires in any other country—say, New York, Buenos Aires or Cape Town. In a short space of time the connections are made and his voice is flashed across oceans and deserts and jungles by the wireless beam links that span the world. Special "chopping" methods are employed that distort his speech for privacy and then, at the receiving stations, it is reassembled again into proper order and his hearer can easily recognize the voice he may know so well.

Sales Organizations

In the task of adequately administering a business house of any considerable magnitude it is essential that costs should be accurately known. Yet the multifarious nature of the tasks performed by separate sections of factories and commercial organizations makes manual costing on a large scale well-nigh impossible and, in any event, too slow. Electricity, however, makes light of the tasks. With electrically-operated adding machines it is possible for work to be checked and the most intricate problems solved with a speed and accuracy quite impossible by human agency. Consequently, sales offices, cost offices and banks, in enormously increasing numbers, are able to utilize these aids to efficiency. They have become a real necessity owing to the increase in business that has to be handled as time goes on. Thus, electricity is called in to aid in keeping pace with the growth of business that it has itself initiated.

The Magic of X-rays

Industry, commerce and the science of healing, as well as purely scientific investigation, meet upon common ground in the use of X-rays. All utilize extensively the properties possessed by the radiations so named, which have many applications. Industry maintains large X-ray plants to aid it in better manufacturing procedure. For example, electric welding is now a standard method of joining

Courtesy of the G.P.O

Linking the voices of Great Britain with those of other countries

The interior of the International Telephone Exchange at Faraday Building, London. Note the names of the foreign cities on the various panels

steel and other metals together in fashioning structures, boilers, ships, water-tanks and the like. It is highly important, however, that the work of the welders should be checked up for flaws and badly-made joints. Since it is often impossible to examine the welds by viewing, X-rays are applied to them. The rays, in penetrating the metal, may be made to affect photographic plates upon which will appear an accurate picture of the whole of the inside of the joint. Thus it can be seen if any blow-holes or other faults have been left that would weaken the structure.

Courtesy of the Central Electricity Board and (top) Phillips Metallix

Electrically welding the cooling tubes in a transformer tank and (*top*) an X-ray photograph of a welded metal joint showing uneven welding on the left and faultless jointing on the right (*see text*)

Customs officers use the rays to detect smuggled goods. Scientists use them in chemical analysis, to examine the structure of atoms, and to determine the best materials for industry to use in its many branches. The penetrative power of the rays is such that only lead will offer a serious obstacle to their path, so that all other metals can be satisfactorily examined by their means.

The application of these wonderful rays to medical practice is well known. Fractures of the limbs, growths and internal maladjustments of many varieties are all revealed. Thousands of people owe their lives to the ability with which internal troubles may be analysed by the aid of X-ray photographs; without such an examination the knife might have had to be resorted to in the hope that the trouble would be found. Our large hospitals are now equipped with huge X-ray departments.

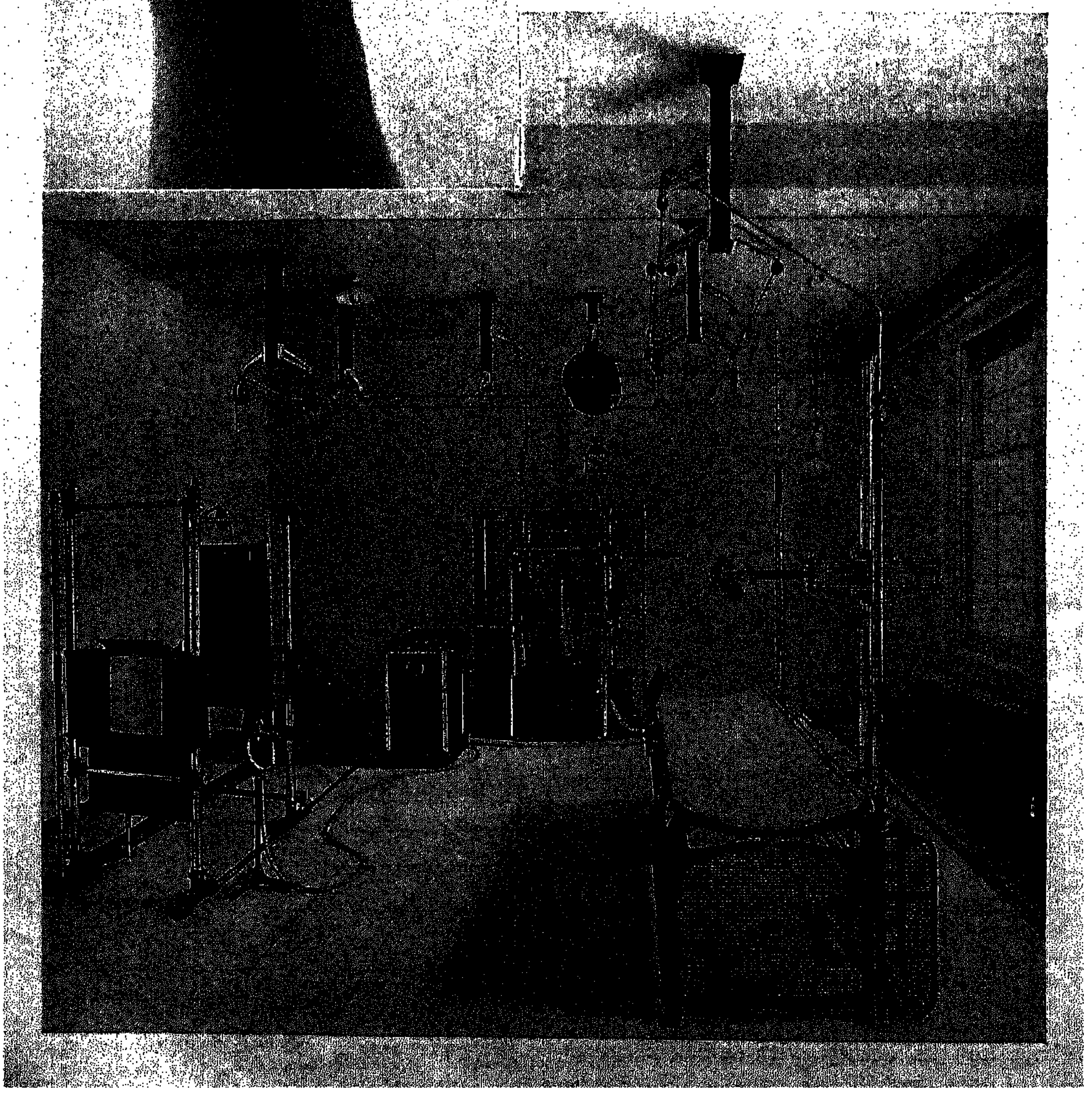
Previously, the work of handling and operating X-ray plant was attended by serious danger. Many pioneers lost their lives, their sight or the use of their limbs in working or experimenting with the apparatus. Now, however, the dangers are well understood, and protective devices

are fitted to all the latest apparatus that make them safe in all circumstances.

Of all the wonderful developments that have occurred in the past decade, through the utilization of electricity, none stands out more than the growth of the automatic telephone. The old days of calls to wrong numbers, and delays in making contact, end with the erection and putting into service of an automatic telephone exchange.

Courtesy of Schall & Son, Ltd.

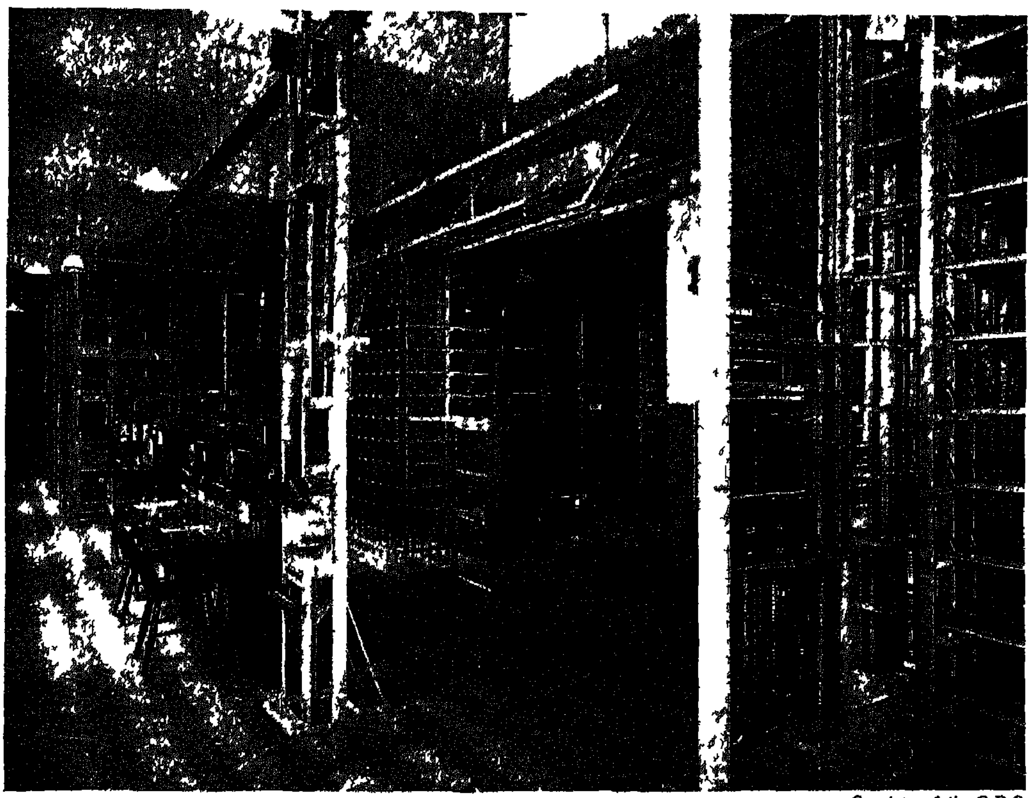
The services rendered to medical science by X-rays are incalculable and all great hospitals now have their departments for this electrical wonder. Here is one at the Children's Hospital, Belfast. Note the heavy insulation of the high-voltage conductors to the apparatus. The X-ray photograph of a broken and dislocated wrist (*left*) is a typical example of the excellence of this form of X-ray application



Thereafter, wrong numbers are the sole concern of the subscriber himself, whilst with almost human sagacity, the apparatus informs him that he is correctly connected to the exchange, that his number is being called, or is engaged, or that he must wait a while for a vacant line.

Nor is the development of this latest wonder of electrical science any less remarkable than its performance The notion began with a collar-box and a few pins, for in this way Strowger, its inventor, first operations are performed so rapidly that no subscriber can dial too fast for the apparatus which, into the bargain charges the calls so made against his account.

From small beginnings, the automatic exchange is fast reaching out beyond towns to include trunk calls across counties, and soon will link continent with continent, by wireless beam inter-country communication. The marvels have long become stranger than fiction—more wonderful and yet so simple in operation—for it is a general



Courtesy of the G P O.

An orderly maze of intricate electrical wiring—part of the interior of an automatic telephone exchange showing the selector racks (*see text*)

worked out his idea of number selection, upon which all modern complicated exchanges work. Now, when a subscriber makes a call, the apparatus itself tests its own lines to see that the call can be successfully made, directs the call to its proper exchange according to the working of the now familiar dial, and then selects from the myriad lines the exact connection required of it, by the number of impulses sent along the line as the subscriber twirls his numbered and lettered wheel. All these axiom that the best electrical apparatus is always simplest in construction.

The motive power of the automatic telephone exchange is the accumulator. It is necessary that absolutely pure direct current ripple-free to the *n*th degree, should be used for this service. Accordingly, the accumulator is used. Two fifty-volt batteries are utilized, one working whilst the other is being charged; but they are very different from fifty-volt batteries as normally understood. Each two-volt cell or unit weighs

up to two tons and its capacity may be 10,000 ampere hours. Yet, when working a normal London automatic exchange it lasts only for eight hours on one discharge.

How the Automatic Selector Works

When a subscriber lifts his telephone for the purpose of making a call on an automatic exchange, the following train of events occurs. He first hears a low tone in the receiver, that tells him he is correctly joined to the exchange, and also that his line is in order. Now, when he dials the letter code of the exchange he wishes to call, impulses of current pass down the line to his own exchange, corresponding in number and position to the letters on the dial at which he stops on each round. These impulses operate what is called a director, which selects from a network of one hundred wires the exchange line corresponding to his dialling. These three "numbers"—for it is the numerical position that really matters here—serve their purpose so far and then the director cuts itself out of circuit, to be ready to join any other subscriber to any other exchange.

Now that our subscriber has been connected to the required distant exchange, he proceeds to dial the number of his call, which is of four figures. Each figure that he dials causes a group of short electrical impulses corresponding to the dialled number to be transmitted along the line to a selector. This selector picks out the thousands, the hundreds, the tens and then the digits, in hundred-line groups of the network, finally to close the line from caller to called and to ring the bell of the distant subscriber so called. The selector then cuts itself out of circuit and becomes available, like the director, for other service. Only the replacement of the receiver of the calling subscriber can disconnect the lines thus joined, so the control of the line is vested completely in the calling subscriber.

Courtesy of the Central Electricity Board

Electricity used for the outside as well as the inside of the home—a flood-lit block of modern flats. Flood-lighting is one of the more recent uses of electric power which has been employed to great advantage for commercial purposes. (*See also illustrations* Chapter XXII)

If, for some reason, a fault should develop in the line, the circuits themselves automatically light lamps to signal to the attendant engineers just where the fault lies. Thus the apparatus works itself and indicates its own difficulties and troubles without outside aid.

Although the engineers responsible for developing such marvellously efficient apparatus to lighten the labours of all engaged in industry and commerce have done as much, too, for domestic appliances, the home use of electricity lags considerably behind the industrial. Nevertheless, the growth still continues. More and more electrically equipped houses are being built or converted, and few persons would desire to return to older methods after experiencing the pleasure of living in a house properly equipped for electrical service.

Electrical heating is a great boon: we walk into a cold room and turn on a switch. In about ten seconds the heater wires are glowing red hot and the reflector is radiating heat across the room. Then, when we leave the room, another touch of the switch stops the fire from working and electricity silently awaits its future call, once again to leap into service. There is no dust, no fume and no smell. Whenever we want it, whatever the quantity we need, electricity is always there—the touch of a switch is all

that is required. We use it so long only as we desire and need its warmth-giving service.

Another use of the incandescent wire that never burns away is in cooking our food. Let us now examine electrical cooking methods. We have a cooker that is almost air-tight, from which little heat can escape. The food is cooked both by radiant and convected heat. We have only to find out how long our dinner should stay in the oven—the makers have already gone to the trouble to do that for us—and turn on the switches as directed for that particular dish. At the appointed time we take out our food ready for the table With a similar dish, the following week, or next year, the same operation will produce exactly the same results.

Coming now to another domestic use, we can heat our water electrically and automatically. The automatic control permits current to flow only when the water drops in temperature. Hot water is stored in a heat-insulated tank and all we have to do is to turn on a tap. Home laundering is simplified beyond recognition it we make due use of electrical appliances. The smoothing-iron can get only so hot and no hotter. We may even have this appliance fitted with automatic heat control, to prevent scorching the clothes and to take into account the differing nature of the materials that are being ironed.

If instead of a bathful we need only a kettleful of hot water, our electric kettle will boil it in a few minutes; and should it boil dry or should we forget to fill it up before switching on, the automatic cut-out will open the circuit and disconnect the appliance.

Nor must we forget artificial lighting. Here we can have the quantity and quality of light directed where we most need it. There is no question of groping for matches, of leaving lights on when we go out, for the purpose of preventing difficulties upon our return. We can even change the colour of the light at will; we can have a precise simulation of daylight if we wish, or the warm orange glow of sunset

Courtesy of the Central Electricity Board

Increasing use is being made of electricity for domestic purposes and where cleanliness, compactness and ease of operation are of paramount importance, it makes a powerful appeal to the housewife. Here is an all-electric kitchen: note the washer, radiator, kettle, cooker and refrigerator

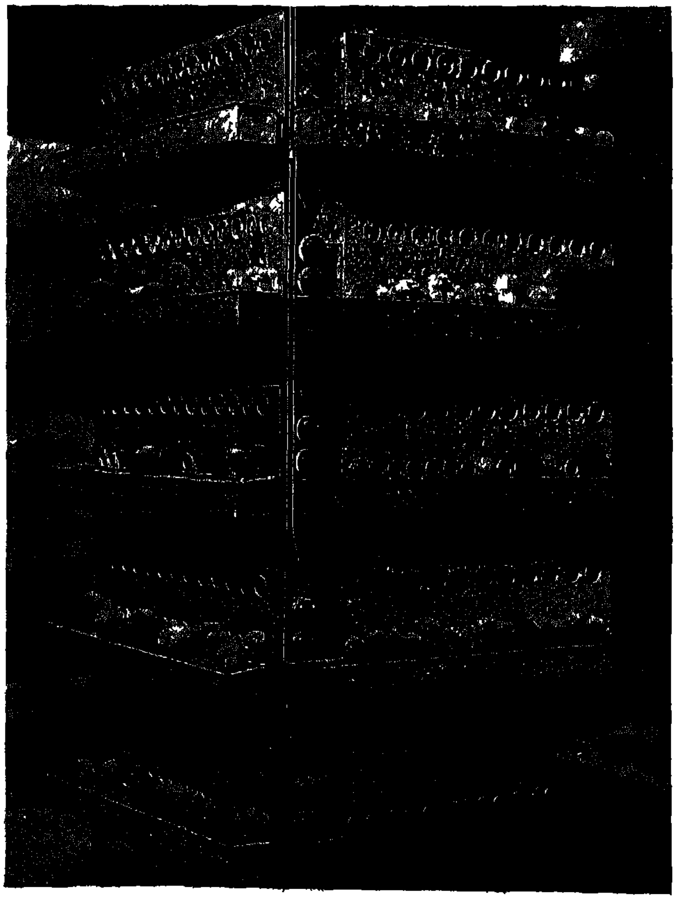
In certain aspects of farming and stock-keeping electricity is an invaluable aid. Thus in large-scale poultry-keeping it has worked a great change. Hens go off laying in the winter time, largely owing to cold weather and the shorter hours of daylight. By means of electrical lighting and warming equipment in the poultry-houses,

the hens live a more annually uniform life, are healthier and produce that extra modicum of eggs which is required to keep poultry farming on a business basis.

But for electricity there could hardly exist vast milk distribution schemes such as we now have. Successful pasteurization of the milk depends largely upon the ability to keep it cool both before and after heating

Courtesy of the Central Electricity Board

The preservation of hygienic conditions on the dairy farm has been made very much easier by the introduction of electrical equipment—milking machines in an electrically lit cow-house



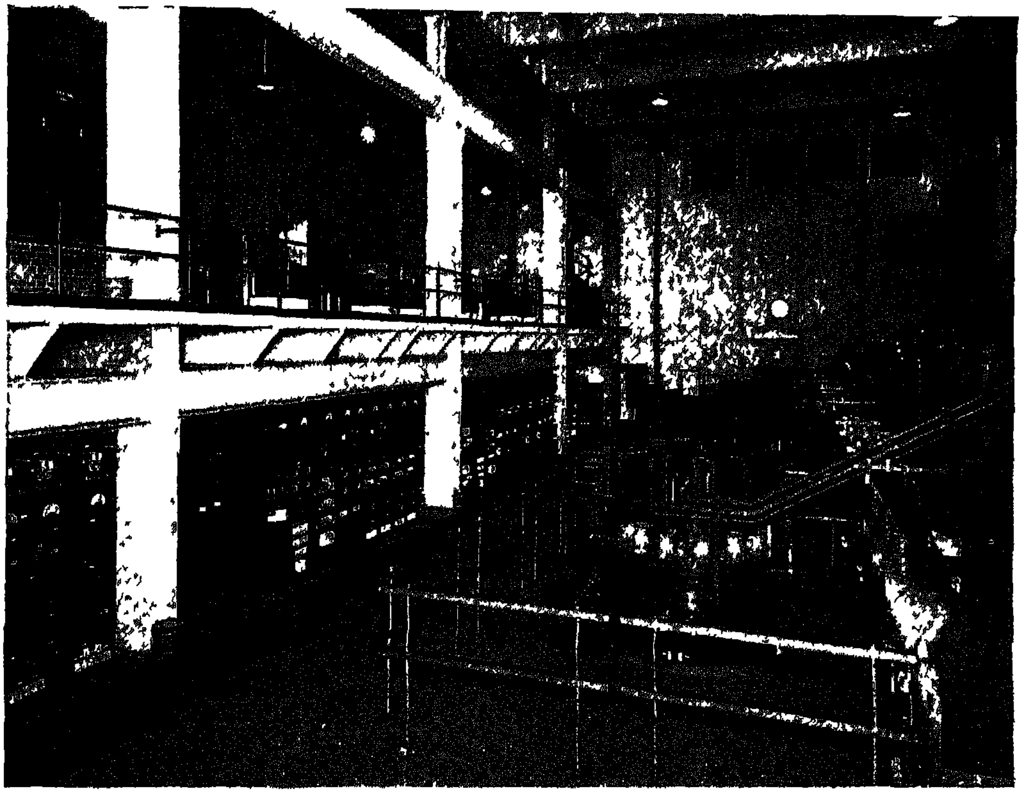
to the critical temperature. This cooling is most efficiently and easily regulated by means of electrically driven refrigerators which are self regulating as regards the degree of coldness they produce.

Electrical equipment plays a large part in the dairy. Milking, milk preservation and cowshed work, butter and cheese making are now carried out with a degree of cleanliness possible only when electricity is the motive power of the apparatus employed. It would be quite impossible to milk huge herds of cows by hand, for the work would never be completed in time; here electrically operated milking machines step into the breach, with their ability to sustain perfect and delicate control.

Even vegetable growing comes under electrical influence where the production of early crops is needed. By electrically heating his soil the grower can

Courtesy of the Central Electricity Board

Both the farmer and the poultry-keeper can profitably enjoy the benefits of electricity in their business—an electric incubator with its cheerful complement



Courtesy of London Transport

London's extensive system of underground electric railways operates so efficiently that little thought is given to the wonderful way in which it is worked. Here is the remote controlled rectifier sub-station at Wood Green whence power is distributed to the corresponding section of track

be independent of many weather vagaries and thus secure adequate return for his outlay. Soil heating of this nature is successfully carried out in garden frames, in glasshouses generally, and also in the open.

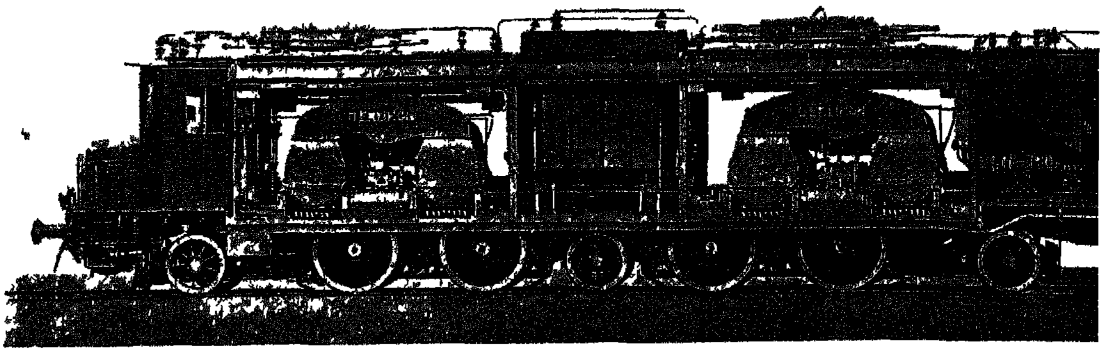
Usually the heating of glasshouses is carried out by some method of hot-air distribution, but this system avoids the basic principle that it is at the roots of the plants that the heat is required. Soil is, however, a bad heat conductor, so that the application of hot air from above is wasteful of energy; artificial manure is needed as much for heat as for the nitrogenous products conducive to plant growth. Electrical heating of the soil should thus produce economies in manure usage.

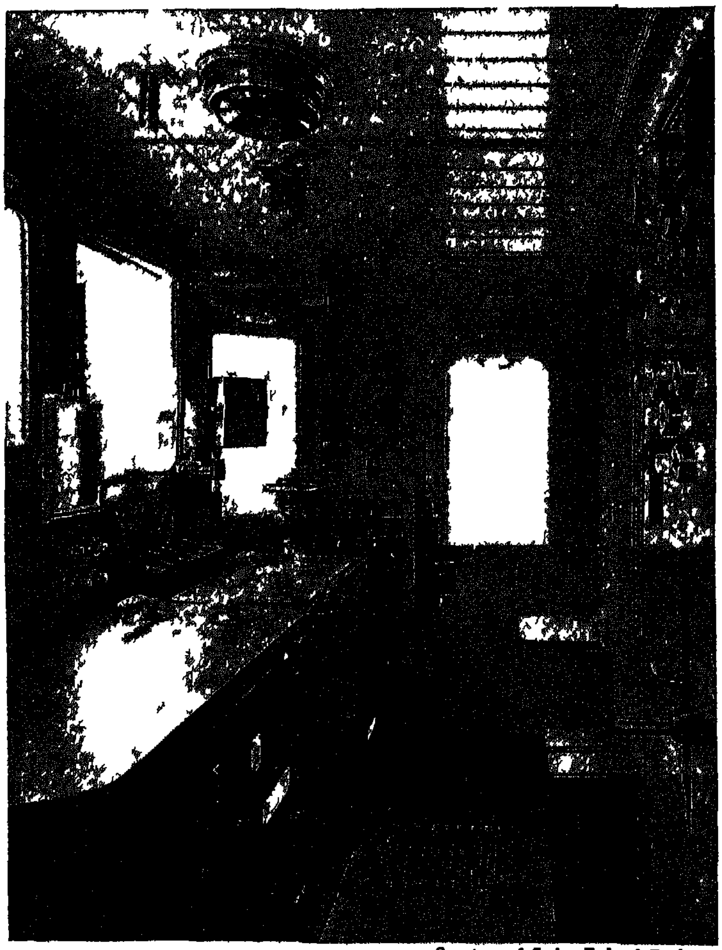
Traction and Transport

Some electrical developments cover both industry and commerce. One of these is connected with travel. Within the last thirty years we have seen the passing of the horse bus and the growing challenge to the steam train. Electric trains are speedy, comfortable and reliable; electric trams and trolley buses convey our millions to and from their work with an efficiency that is entirely unapproachable by other means.

The horse-drawn delivery vehicle is disappearing from the streets of towns. It is true that the petrol vehicle ousted it, but the latter in turn is challenged by the electrically driven delivery van. Bakers, milk roundsmen and the like find the electric truck more efficient and less costly in running than the petrol vehicle, whilst public authorities all over the country use electric vehicles for refuse collection. Electric vehicles draw their supply of current from a battery of accumulators which they carry. When the vehicles return to the garage at night, the batteries are thereupon put "on charge." Automatically regulated plant ensures that the batteries will be fully charged by the next morning, without the need for supervision during the night.

The electric train, in the well-known





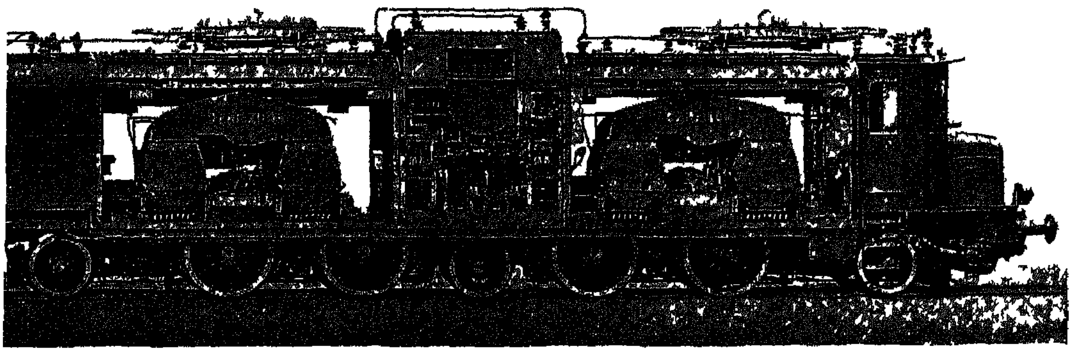
Courtesy of Swiss Federal Railways

Lacking natural coal resources, Switzerland has actively developed her abundant water power for the production of electricity Almost the entire railway system of the country is now electrically operated and some of the most powerful locomotives in the world run over it No. 11851, here illustrated, is one of the latest types It is articulated, has a length of 111 feet, and is fitted with 16 motors totalling 8,500 h.p. The driving cab (*bottom*) is an admirable example of clean design. (*See also illustration*, Chapter XVIII)

Underground system, has been with us for years—long enough to become commonplace — but the application of electrical traction to main line and surburban traffic is recent. The efficiency with which such systems can run is clearly seen on the Southern Railway where the lines have now been electrified right down to the coast. About a quarter of an hour has been taken off the train time between London and Brighton as a result of substituting electric trains for steam. In general, owing to the increased efficiency of the electric system, three trains may now run with safety over the same rail track during the same time interval that previously was allotted to one steam train.

No doubt further track mileage over longer spans will soon be electrified, and the time should not be far ahead when even long-distance trains will be electrically propelled.

In other parts of the world electric traction has also been widely developed and in certain countries, as for example Switzerland, the railway systems are gradually being converted exclusively to electricity.



CHAPTER XXVII

LAKES OF PITCH AND SEAS OF SALT

IT is not often that Earth spreads the treasures of her storehouse at the feet of Man. To find silver he must usually delve deeply. Gold and diamonds are hidden in desolate places; oil and coal lie stored in the very bowels of the earth. Yet here and there Earth exposes her riches. The great lakes of pitch and the seas of valuable salts lie open for utilization by Man.

Lakes of Bubbling Pitch

By far the largest and certainly the best-known pitch-lake in the world is that on the British island of Trinidad in the West Indies. This brown-black lake is of relatively pure asphalt or bitumen, and geologists say that it owes its existence to volcanic disturbances. The rocks in this region are oil-bearing sands and clays. Long ages ago the oil from these sands seeped in tremendous quantities into a mud volcano where the lake now lies. Gas, oil, sand and clay churned and bubbled together for thousands of years. As the lake became older the movement became less and less until the present comparatively quiescent stage was reached. There was left a thoroughly mixed substance consisting of asphalt, colloidal clay and fine silica. With the gradual cooling the asphalt hardened. Here and there large pieces of clay and sand apparently floating in the lake have the appearance of islands, since they support grass and other small plants.

Although apparently quiescent, the lake nevertheless is in a state of complex motion which gradually obliterates footprints and any holes that are dug in the surface. Near the centre the pitch is always liquid, and can be seen slowly bubbling up. In the daily digging operations, however, the men work at the same hole day after day and yet it never gets any deeper than some two feet. This is due to the upward thrust of the pitch in the pit bottom, caused by side pressure which balances the digging rate. If the digging is stopped for two or three days the pit bottom rises to the level of the lake surface, but the sides do not move.

A curious instance of these unceasing movements occurred in 1928. A tree trunk began to push its way in a perfectly upright position through the surface. When six feet of the trunk was showing, workmen sawed it off to secure the log. After sawing, the tree still continued to rise for a further ten feet and remained stationary for a few days. It then gradually tilted, and when almost horizontal with the surface, began to sink again until within a few days it had completely disappeared. So far it has never again been seen. Experts who examined the sawn-off log estimated that the tree had been buried in the lake 4,000 to 5,000 years.

Wonders of the Trinidad Lake

The Trinidad Lake is about 125 feet above sea-level and lies three-quarters of a mile from the seaside village of La Brea. In area it is variously estimated at 100 to 127 acres. It is only within the last few years that an accurate calculation has been made of the depth of the asphalt deposits of Trinidad. In 1860, investigators believed these to extend to a depth of twenty feet, though

they hesitatingly conceded a further ten feet as possible. Borings taken in 1920, however, showed a depth of 150 feet, and even then a rock or earth bottom was not reached. The boring tubes were broken and lost, but re-appeared months afterwards in different parts of the lake

A few years later another attempt was made, using a three-inch iron pipe into which was inserted a one-inch steam line. This boring was successful and established the maximum depth of the lake to be 285 feet. At each fifty feet a test for composition and quality of the asphalt was made, and in every case the samples were identical with the surface material removed during the past years

The asphalt wells up in low bulging masses which are separated from one another by narrow channels in which rain pools lie. Even if this undulating contour is disturbed by digging, within a few days the surface of the lake resumes its old familiar shape. The road from the lake to the village of La Brea runs over a bed of asphalt and is slowly but persistently moving towards the sea, somewhat like a glacier.

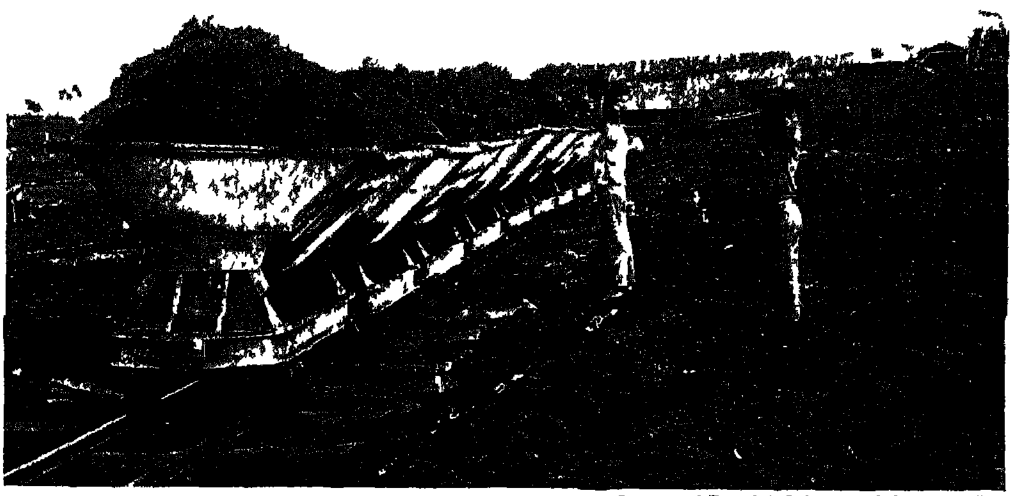
The earliest record of this unusual deposit in Trinidad comes from the diary of Sir Walter Raleigh, who visited the island in 1595. He wrote: "From thence I rowed to another part, called by the naturals 'Piche' and by the Spaniards 'Tierra de Brea' . . there is that abundance of stone pitch, that all the ships of the world may be therewith loden from thence, and wee made trial of it in trimming our shippes to be most excellent good, and melteth not with the sun as the pitch of Norway, and therefore for shippes trading the South parts very profitable."

Little seems to have been known of the lake or much use made of the pitch until the 19th century. In 1807 Dr. Nugent of the Geological Society stated he heard it related that "when the Spaniards undertook formerly to prepare the pitch for economical purposes, and had imprudently put their cauldrons on the very lake, they completely sank in the course of a night so as to defeat their intentions." From this it would appear that attempts were made to use the asphalt and commercialize the deposit.

In 1848, Admiral Cochrane, Earl of Dundonald, tried to use the Trinidad asphalt as fuel for his coal-burning flagship. He mixed it with coal in the proportion of two parts of

Courtesy of Trinidad Lake Asphalt (Overseas) Ltd.

The surface of the natural lake of pitch at Trinidad in the West Indies. Estimates give its area as 100-127 acres and its depth at 285 feet. The asphalt refinery is seen in the background



Courtesy of Trinidad Lake Asphalt (Overseas) Ltd.

Crude asphalt is dug from the Trinidad Lake, in blocks weighing about 85 lb. each, by native labourers who transport the heavy loads on their heads. A light railway carries the asphalt to the charging stills at the refinery

asphalt to one of coal and claimed that the experiment was a success. Certainly he made valiant efforts to show the British Government what a neglected treasure lay in the Trinidad pitch lake. This is the same Cochrane who is said to have prepared plans for gas warfare, using sulphurous fumes for the purpose. He took out several patents to use pitch for coating and insulating wire, for improving pipe junctures, for construction of drains, waterways, reservoirs and for making pillars, pedestals and ornamental objects.

To-day the Trinidad asphalt lake, although the property of the British Crown, is controlled by a British company and worked by an American concern. The exported asphalt is distributed by both British and American companies. Whereas in 1857 the quantity of asphalt shipped from Trinidad was 1,800 tons, the amount now taken from the lake each year is 200,000 tons or more.

The asphalt is removed by labourers using pickaxes. This has so far been found the most efficient method owing to the nature of the material and the low cost of labour. Each shift of some 220 to 250 men is divided into gangs comprising one digger and five loaders. Each gang has its own place along the narrow twenty-four-inch rail-track with its string of cars for hauling the asphalt to the refinery. The loaders are often called "headers" because they carry on their heads the asphalt lumps, which often weigh up to 100 pounds. Unless there is need of rush work to complete loading a vessel, digging is not carried on after midday, owing to the heat of the sun and the consequent strong odour of the asphalt. One big difficulty arises with regard to the rail-tracks, for the lake is continually moving and the tracks have to be relaid every day.

How Asphalt is Refined

As dug from the lake the asphalt is an extremely uniform mixture of gas, water, mineral matter and bitumen. Comparing it with other natural asphalt deposits, the Trinidad material shows a very regular bitumen content. The natural form of the materials composing the asphalt is more or less an "emulsion," and it has to be refined before being of commercial value.

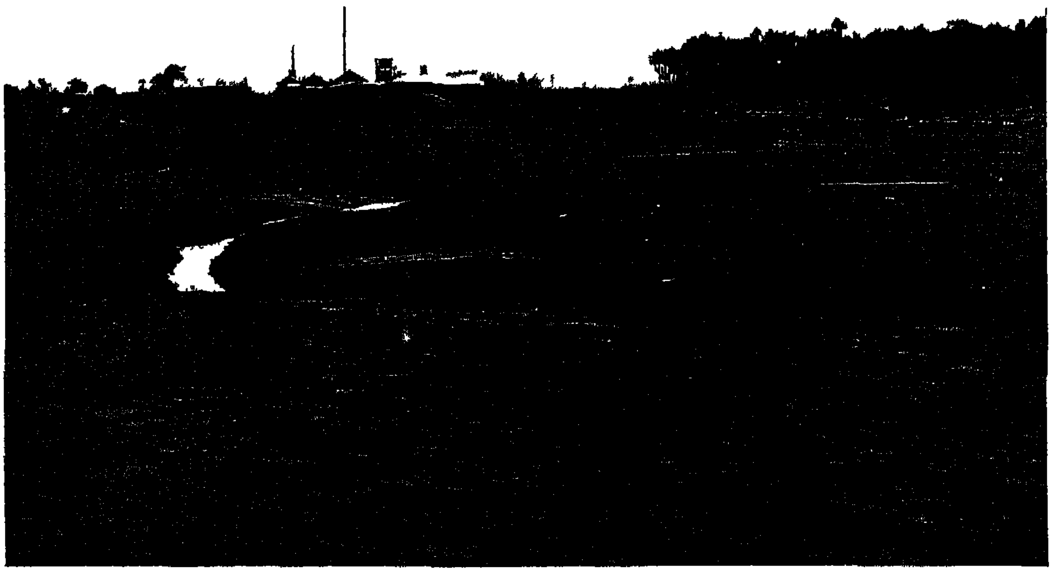
In the adjoining refinery plant, high-pressure steam is forced through the asphalt to melt it. The black molten mass then runs through a fine screen and is poured into

barrels for export. When the asphalt arrives *at its destination* it must first be fluxed or softened by mixing into it a proportion of residual petroleum. The resultant mixture is known as an asphaltic cement, of which there are various grades.

The asphalt from Trinidad Lake is of such a uniform character that it is used for road surfacing in all the main countries of the world. It has been estimated that a surface area equivalent to that of a road over twenty feet wide and extending entirely round the world had been constructed with Trinidad asphalt by 1927. This is quite apart from its other uses, which have been increasing of recent years. Roofing sheets, damp-courses, floorings, anti-acid tanking, pipe-coverings and joint fillings are some of the other things made from ready-made pitch that Nature presents to Man in an apparently inexhaustible supply.

Trinidad asphalt has been found to stand great extremes of climate. For nearly half a century it has withstood the cold of the Arctic North and the heat of the Tropics; it stands up to the destructive action of traffic and has in the main proved more durable than synthetic asphalt. Singapore, Tokio, Durban, Bombay, Cairo, Dunedin, N.Z., Washington, and London all have some of their more important thoroughfares overlaid with the black Trinidad "pitch."

A few miles from South Trinidad across the Bay of Paria lies Venezuela, a veritable treasure house of the world. The eastern regions of this republic, especially the delta of the River Orinoco, contain many asphalt deposits. Some adjoin oil districts, but are very small and not yet worked, whilst others are of definite commercial value. Most famous of the Venezuelan pitch pools or lakes is the Bermudez Lake in the eastern state of Monegas. The lake is much more extensive than that in Trinidad, and was for many years believed to be a richer deposit. Careful boring, however, showed that though it was more extensive it was much shallower. The asphalt from Bermudez is much softer than Trinidad pitch, because it contains less mineral matter. The lake is worked by an American company, which ships the asphalt to Trinidad and thence to various other countries.



E.N.A.

Similar in appearance to the Trinidad Lake, the one at Bermudez in Venezuela, is more extensive but not so deep. The vegetation has been largely cleared from the lake to render the asphalt accessible

On the Venezuelan coast almost opposite Trinidad is a small town called Pedernales Here, even on the seashore, great lumps of asphalt lie embedded in the black mud that serves as a beach. Along the main street, which has not been metalled, it is difficult to distinguish between dirty pools and the black patches of natural asphalt. At Pedernales, before the Great War, a German company erected an asphalt and oil refinery, but it did not prove a commercial success. Venezuela has long been known as a source of asphalt, and there are indications of the existence of petroleum, the parent mineral, all over the northern and western states.

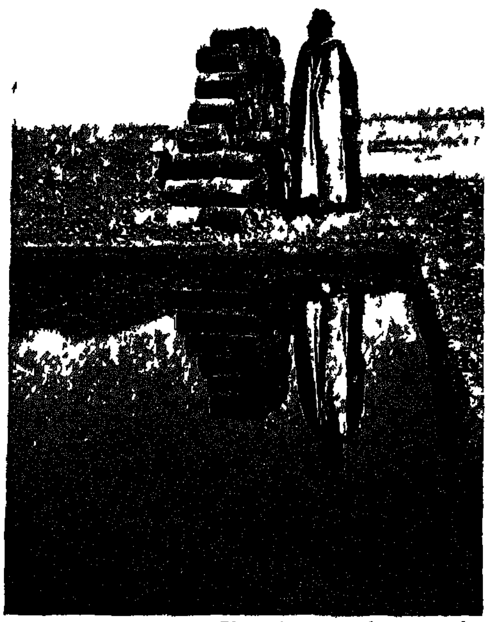


Photo American Colony, Jerusalem

South of Mosul in Iraq are numerous bituminous wells which are worked commercially—a bitumen storage pool at Gayara

Colorado, one of the west central States of America, is immensely rich in minerals. It has enormous fields of bituminous coal and near them both petroleum and asphalt are found in lesser quantities. Some of the asphalt wells up into small pools and, like the asphalt of Trinidad, is easy to dig.

Although bitumen in its various forms is to be found in almost all parts of the world, it is only here and there that it is so easily accessible for commercial use as in the pitch lakes. More commonly it is found impregnating some porous rocks like limestone In Dalmatia, the Adriatic coastal province of Yugoslavia, the limestone is so bituminous that it can be cut like hard butter. Walls of houses in the vicinity are built of these slabs and then set on fire. The bitumen burns out, leaving walls of clean white limestone The roof is then put on and the house completed.

Bitumen—the name was given to the black mineral by the Romans—has been known and used for thousands of years. The ancient Egyptians employed it for embalming their dead, and the "slime" with which the ark of bulrushes that hid the infant Moses was daubed was pitch or bitumen. This "slime" of the ancients came mostly from the "slime pits of Siddim," in the region of the Dead Sea Even to-day pieces of asphalt float occasionally to the shore and are collected by the local inhabitants for a protection against worms and grubs in the vineyards.

Seas of Salt

The waters of the Dead Sea in Palestine are the richest source of easily-accessible natural salts in the world. Ordinary ocean water has a salinity of 4 per cent. to 6 per cent, but the Dead Sea contains 23 to 25 per cent. of salts. No fish or other living thing can eke out an existence in its waters.

Yet in ages long past the Dead Sea abounded in fish and plant life, for it was then a part of the Mediterranean. Later, an extensive volcanic upheaval of the sea-bed caused the formation of the Gilboa and the Lebanon mountains, thus putting a land barrier between the Mediterranean and its arm, the Dead Sea. At the same time a fracture of the rocks caused the River Jordan-Dead Sea depression to open from north to south. The waters of the Jordan and its tributaries, seeking the lowest level, poured southwards into the low-lying Dead Sea.

At one time, during a period of great floods and rains, this salt, inland sea extended its shores far beyond their present limits. The surface rose to a height well above that of the Mediterranean and some 1,400 feet above its present level. Along the margin of that extended sea are still to be found remains of its fauna. A dry period followed and the fresh water coming in from the Jordan river did not balance the amount of water lost each year by evaporation. During following centuries the Dead Sea gradually shrank. Thus there was left an exten-

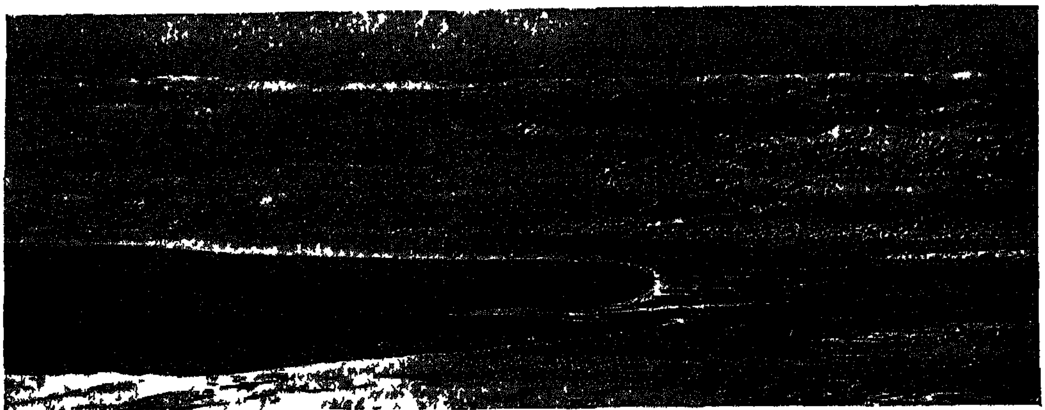
widening "shore" where lie deposits of marl, clay and various useful salts. Only the hardiest of grasses and salt-plants are to be found on these desolate expanses.

Two features of the Dead Sea have developed since it began to shrink. One is a peninsula, the Lisan or Tongue, which projects from the eastern shore; and the other the Jebel Usdum, a hill on the south-west shore. Both were caused by an upheaval of the floor of the sea. Immediately to the north of the Lisan, the water is at its greatest depth—1,310 feet. To the south of the peninsula it varies from three to thirty feet deep.

In recent times certain observers have stated that this strange salt sea is almost stable, having a few centuries ago reached a balance between evaporation and incoming water supply. On the other hand, a survey in 1883–84 showed that the level of the water had risen nearly twenty feet; while by 1900 it had risen a further six to eight feet. Other observers believe these risings were temporary and state that the mean level over many years is now constant. The rise in level is mainly accounted for by the gradual but constant carrying down of silt by the Jordan —silt which is deposited in the river's delta and on the sea-bed. Another noteworthy point is that the climate around the salt sea is becoming more moist and the rainfall is consequently higher, thus bringing a further supply of fresh water to the Dead Sea.

Before this inland sea reached its more or less stable condition, it lost enormous quantities of water; for to-day the Dead Sea lies 1,300 feet below the level of the Mediterranean and is the lowest sheet of water on the earth's surface.

The Dead Sea is forty-seven miles long and about ten miles broad at its widest part. Its average depth is 1,080 feet. The surface level varies to the extent of about twelve feet, according to the seasons. In winter, small torrents from the hills in the east and west add their contribution to the steady flow of



Courtesy of Imperial Airways

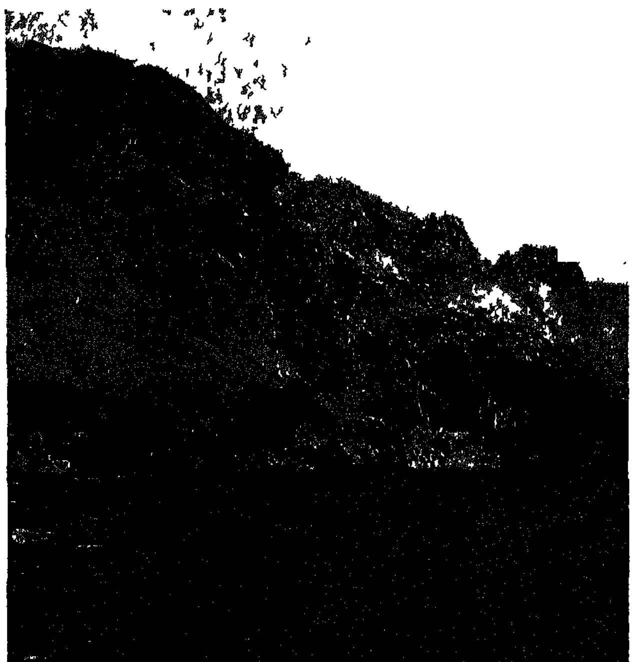


Photo American Colony, Jerusalem

On the south-west shores of the Dead Sea stands Jebel Usdum—a remarkable hill of rock-salt from which wandering tribes have for centuries collected salt. The view (*top*) taken from Mt. Nebo (2,643 ft.) shows the Dead Sea on the left with the mountains of Judea in the background. (*See also illustration, Chapter XIII*)

the Jordan. In summer, the majority of them are dry and only Jordan pours in its steady 6,000,000 tons of comparatively fresh water daily. This heavy inflow is carried off by solar evaporation, the vapour forming fairy-like clouds which float leisurely over the surface of the waters.

In spite of its name, which suggests desolation, nothing could be more beautiful than this sea of vivid blue. The varied effects of light upon it, the grandeur of the deep gorges and the filmy vapour clouds which hang over the waters like a veil make it one of the world's beauty spots.

It was not always known by its present dismal name. The Israelites called it "the Salt Sea," "Sea of Arabah" and the "Eastern Sea"; the Arabs knew it as the "Sea of Zoar," the "Stinking Sea" and the "Sea of Lot." To Josephus, the Jewish historian, it was the "Asphalt Sea" or the "Sodomitish Sea." It was the Greeks who first called it the Dead Sea.

Quest for Lost Cities of the Salty Plain

The quest for the lost cities of the Plain has often been pursued. An expedition in 1924 returned convinced that Sodom, Gomorrah and Zoar had stood in the south-east corner, on the lower reaches of perennial streams that are now lost under the waters of the Dead Sea. This same expedition reported on the excellence of the atmosphere during the period of their investigations. It was suggested that with proper irrigation the arid land could be made into great tropical gardens or oases, each perhaps 10,000 acres in extent. The establishment of a motor-boat route, and a good motor road to Jerusalem and the coast, it was thought, would soon attract many to a new health resort with such glorious scenery.

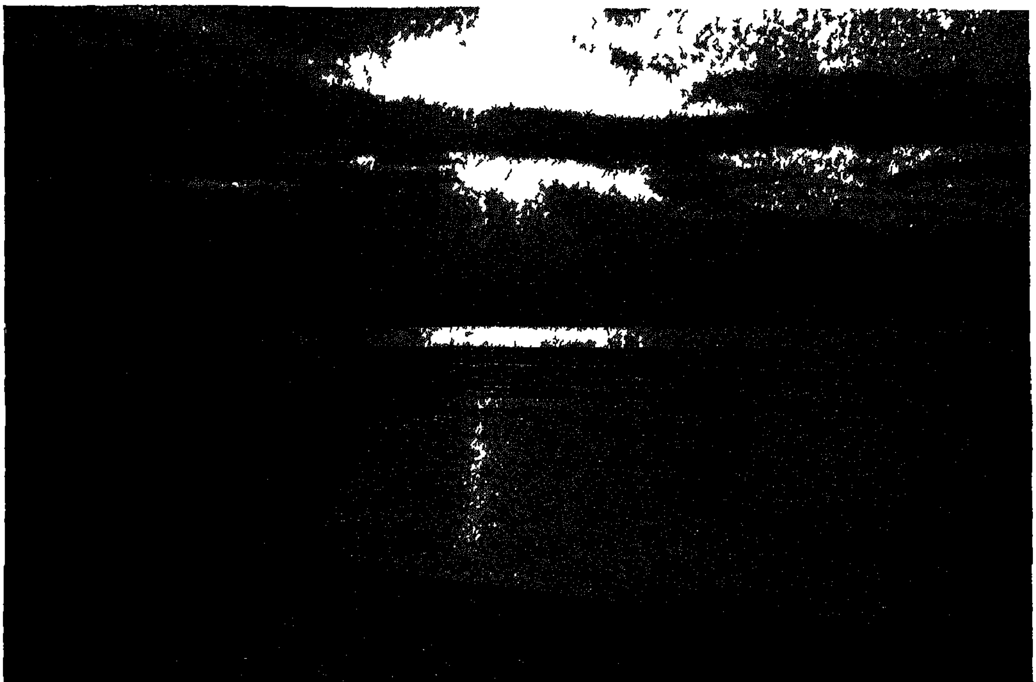


Photo American Colony, Jerusalem

Sunset over the lowest sea in the world. Despite its depressing name, the Dead Sea is far from being an utter desolation. The filmy vapours—caused by evaporation—which float above its waters are often responsible for most beautiful light effects

But apart from such attractive suggestions, the Dead Sea itself is arousing great interest in the minds of civil engineers and company promoters. For the value in potash and other important salts available in the Dead Sea is veritably enormous. One litre of this intensely salt water taken at a depth of 120 metres contains 24·5 per cent. of solid matter, mainly minerals. Under analysis this mineral content has been found to have the following proportional composition:

	Per cent.		*Per cent.*
Chlorine .	67·86	Bromine .	1·98
Magnesium	16·81	Potassium	1·62
Sodium .	10·20	Calcium	[illegible]

Besides these there are also traces of sulphate, carbonate and silica.

The magnesium, sodium, calcium and potassium are present as chlorides. The soluble chloride of magnesium gives the water a nauseous taste, and the chloride of calcium gives a smooth oiliness to the liquid. Such water is naturally very dense, and a man swimming in it is so buoyed up that his shoulders are out of the water all the time. To walk in it is difficult enough, since as soon as the water comes up to his armpits, the bather is floated off his feet. Unless he dries very carefully he will find himself coated, too, with a disagreeable stickiness deposited on his skin by the salts in the water. The sodium chloride or common salt content crystallizes out as the water in the Dead Sea evaporates, and is easily collected. Nomads for centuries have gathered salt from the region of the hill of Jebel Usdum.

All salt recovered at the present day is handled by a government monopoly. But the government of Palestine realizes that much more could be made from the commercial exploitation of the many other salts of the Dead Sea. Ten years ago (1926) it invited applications for the rights to develop the mineral resources of this strange lake, and *many interesting investigations* have resulted.

A year or two ago M. Pierre Gandillon, a French engineer, put forward a remarkable scheme which received much support from other eminent engineers. This scheme, or some modification of it, will most likely be ultimately used for the full development of the Dead Sea resources. M. Gandillon's plan was to utilize the sun's heat to evaporate out the water of the sea and so cheaply to recover its salts. For eight months of each year the sun's heat would be sufficient for such evaporation. But the waters of the Jordan would have to be prevented from entering the Dead Sea, and some method adopted to keep the Dead Sea depression naturally filled with salt water. The proposal was to substitute for the fresher water of the Jordan the salt water of the Mediterranean. This would be quite possible, for the Mediterranean lies 1,300 feet higher than the Dead Sea. The concentration of the Dead Sea water, say the engineers, would increase and become an inexhaustible fund of increasing wealth, with a much greater output than

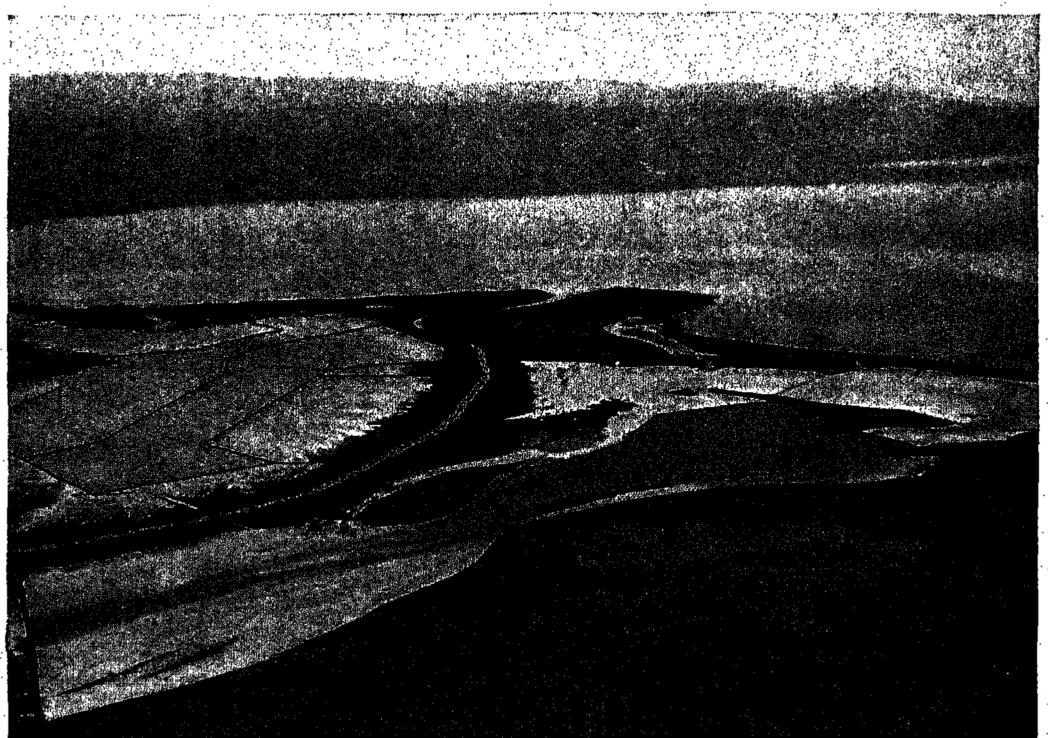


Photo: American Colony, Jerusalem

Where the River Jordan flows into the Red Sea. An air view showing the wide salt evaporating pans near the river's banks and the mountains of Moab in the distance

the famous potash mines of Alsace and Stassfurt.

By this arrangement M. Gandillon estimated that in one second there could be recovered by solar evaporation: $16\frac{1}{2}$ tons chlorine, 4 tons magnesium, $2\frac{1}{2}$ tons sodium, $\frac{1}{2}$ ton bromine, and $\frac{1}{3}$ ton potassium. He proposed to utilize the diverted waters of the Jordan to irrigate the surrounding parched countryside. There would be great initial difficulties in carrying out such a scheme, since the soil for many miles around has a strong salt concentration. Even the soil as far off as Jericho, some seven miles away, has a 10 per cent. salinity. Thus it would first be necessary to desalinate the soil by successive irrigations before the surface layers would be capable of growing crops. Electrical energy might be made available by the fall of the Mediterranean water in its descent to the Dead Sea. There would be many problems to solve in thus connecting the Middle Sea to the Dead Sea, but the difficulties need not be insuperable; if the returns from the scheme seemed worth while, the troubles could be overcome.

Great Salt Lake, Utah

Another large body of concentrated salt water is the Great Salt Lake of Utah in the U.S.A. It is in a low-lying region bounded by higher land on all sides. Centuries ago this Great Basin, as it is called, was completely occupied by a vast sheet of water, 19,000 square miles in area, known to geologists as Lake Bonneville. Seventeen distinct shore levels can be traced on the mountainsides, showing the irregular shrinkage of the Bonneville lake. Great Salt Lake and Lake Sevier, some distance to the south but in the Basin, are shrunken remnants of this original inland sea. The Basin itself is but the bed of the earlier lake. The soil here is very barren and dry, but when irrigated yields excellent crops.

The eastern side of the Basin is the best irrigated, since plenty of water is available in the many streams flowing down from the Wasatch range. Here and there, on the level bed of the Basin, steep isolated mountain ranges rise several thousand feet above the plain. Streams from them and from the Wasatch have no drainage outlet, but flow to the lowest levels, leaving dreary mud flats in the dry season. In the larger depressions water remains all the year round, although much is lost by evaporation during the hotter months. Such lakes are saline, and the largest of them is Great Salt Lake; during the wet season it is some 2,000 square miles in extent. One-third of this area, however, is lost by evaporation annually.

Although Great Salt Lake is fed by the Bear River on the north, Weber River on the north-east, and Jordan River on the south-east, its waters are much denser than ordinary ocean water. Its average salinity is 17 per cent. to 21 per cent., somewhat less than that of the Dead Sea water.

Summers in the Great Basin of Utah are usually disagreeably hot, but this heat is useful for salt production. The saline waters of the Great Salt Lake and other smaller lakes in the Basin are allowed to flow into great evaporating pans. Such artificial pans or pools are extensive in surface area but are made shallow, to allow a maximum amount of water to be exposed to the sun's heat. As the water evaporates, the salts crystallize out and are raked into heaps, allowed to dry for some days and then lifted from the pans. A final washing and drying is given before the salts are saleable. About 85,000 to 90,000 tons, mainly of common salt, are produced annually in Utah by means of solar evaporation.

During the Great War, when phosphates were greatly needed, large supplies were mined from deposits around the Great Salt Lake, especially in the Salduro Marsh area. Since the war, however, this phosphate recovery has stopped, for the mines are unprofitable.

Where Bathers Cannot Sink

Saltair, a town on the shores of the lake, is a popular holiday resort for the inhabitants of Salt Lake City, the capital of Utah, some fifteen miles to the east. The concentration of salt in the water makes swimming a pleasure, since it is quite impossible for anyone to sink.

South-west of the Great Salt Lake is a broad flat stretch known as the Desert. It is more arid than any other part of the Basin and lies so low that in spring it is partly covered by water. To the south is the salt Sevier Lake, fed by Sevier River. During the dry season this lake of 188 square miles completely evaporates, leaving large deposits of impure common salt and sulphide to a depth of some five inches. An immense irrigation scheme is in course of construction to fertilize great areas in the Basin. The water of all streams in Utah is public property and the State engineer has entire charge of its distribution.

Up to 1848 Utah was a Mexican possession and had been part of the country explored

F N A

A sea of salt in the New World—the Great Salt Lake, Utah. Seen from the Garfield Beach it is scarcely one of the world's beauty spots, but the Great Basin—of which the lake is a part—is commercially productive, having an output of 90,000 tons of salt annually. The rocky islet (*top*) is characteristic of many in the lake

by the Spaniards in the 16th century. Later, Catholic priests journeyed as far as Sevier Lake, hearing tales from the Indians of a great salt sea farther north. But it was not until 1811–12 that white men really explored the Great Basin, although the account they left of this region was vague In 1825, to settle a wager as to the outlet of the Bear River, a man named Provost traced the river's course to the lake. He was surprised to find it salt, and concluded that he must have reached a long inlet from the sea.

Settlement in the Basin did not come about until some years later, when in 1847 the first company of Mormons decided to found there a permanent home. Agriculture was difficult, but irrigation was practised from the beginning. It was only when the mineral wealth of the country was discovered that men came rushing to neglected Utah. Now it is one of the greatest metal-producing states in America.

How Salt Pools form in the Desert

The great desert regions of the world often hold salt pools or lakes. Since the rain supply is scanty and river water either non-existent or negligible in amount, little fresh water replenishes these pools. As centuries pass, their waters evaporate and the concentrated salts drawn from the surrounding soil are left behind. In the Sahara, several such salt pools give wandering tribes enough salt for trading. In the Gobi Desert many pools are brackish, some tasting of common salt and others of soda. The salt pans of the Australian deserts, especially those of the west and south, are merely shallow pools containing in solution the salts from the soil around. Sheets of water in these regions are marked on maps, but often they are not true lakes. The name of one of them, Lake Disappointment, tells its own story.

The province of Buenos Aires, in Argentina, has more than 600 small lakes, most of them salt or brackish. The largest sheet of salt water in this part of the world is Mar Chiquita in Cordoba. The rivers which flow into it are somewhat saline themselves and, having no outlet to the sea, they add to the concentration of the lake. Quite a number of salt or brackish streams are to be found in Argentina. Their names, Salado and Saladillo, indicate their character.

Rock salt is found in many parts of the world and is generally believed to have been formed by the evaporation of salt inland seas such as the Dead Sea. In succeeding ages it has been buried and has become rock-like under the compression of overlying soils and rocks. To make it of commercial value it has to be mined, crushed, washed and dried. Such beds of salt are found in the Punjab of India, at Wieliczka in Poland, in England, Saxony and the U.S.A.

There are also found in various parts of the world lakes of an alkaline character. The salts they hold make the water undrinkable, but the dried minerals recovered are of use in commerce. Several alkaline lakes lie in the south-east of Alberta in Canada, but have not yet been much exploited; the soil in the region round about is also alkaline and cannot support many crops. In the drier parts of Wyoming and California alkaline lakes are found from which small quantities of mineral salts are extracted.

The district of Magaidi in Kenya, East Africa, possesses a lake of carbonate of soda. Water coming from the surrounding higher land has evaporated in the hot sun, leaving behind the deposits of soda. Successive rains and evaporations have added to the deposit until the alkalinity of the lake is such that the surface is now quite solid. Natives cut the soda into huge blocks and pack it ready for shipment. Despite difficulties in transport, the working of the Magaidi Soda Lake is a profitable business. *See illustration*, CHAPTER XXXIX.

CHAPTER XXVIII
THE CHEMIST'S GIFTS TO MANKIND

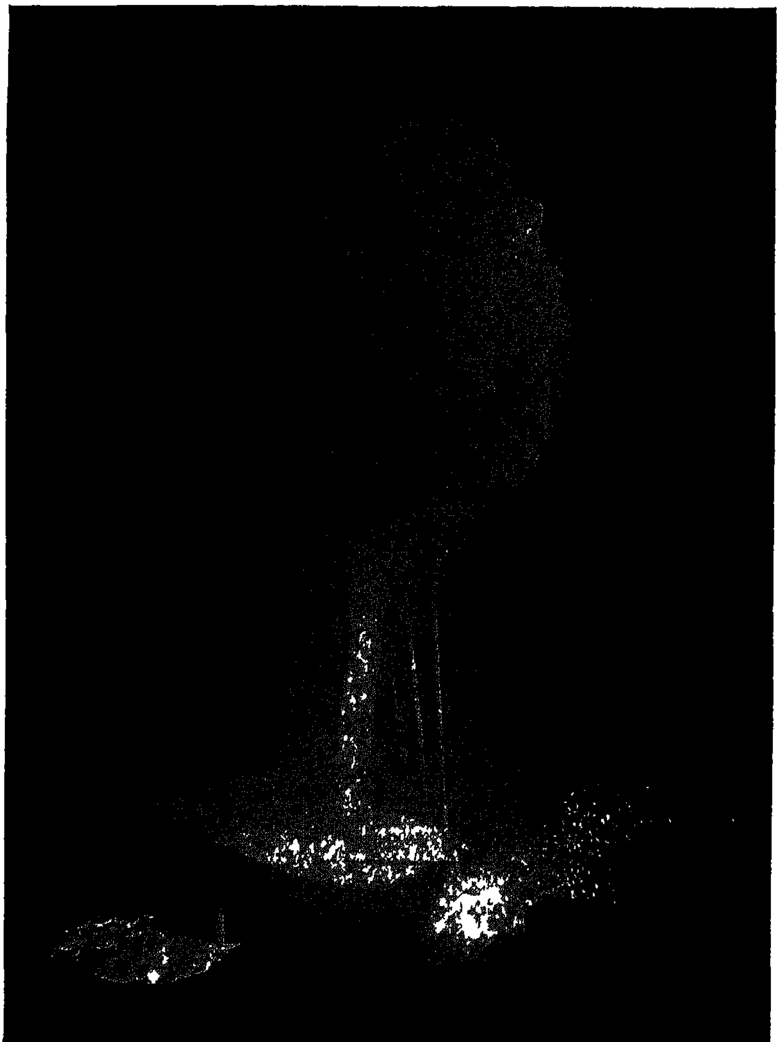
MAN has been described as a tool-using animal, but the materials available for tool-making in ancient times were very few. The use of stone and bone preceded that of any metal. Later, metals procurable either in the natural state, like gold and copper, or by very simple operations came into use before those which were more difficult to obtain. Archæologists divide prehistoric times into the Stone Age, a period prior to 3,000 B.C.; the Bronze Age, which lasted for some 800 years until about 2,300 B.C.; and the Iron Age, when iron began to be used in any quantity.

Iron and Steel

There seems reason to believe that the first iron known to man was of meteoric origin. The first iron produced from ore was most likely the result of an accidental smelting—perhaps of lumps of surface ore fused in a forest conflagration—or a lump of iron ore may by chance have been banked on a nomad's camp-fire. Another possibility

that his fire was built against a rock with an iron content. Having discovered the metal, and finding that it yielded a more useful tool than either stone, bone, or copper, Man began to make more rapid progress. Through the medium of this malleable metal, capable of being converted into a myriad implements, he was able to fashion tools and weapons that gave him mastery over the brute creation, and also over hitherto intractable materials like hard and durable stone.

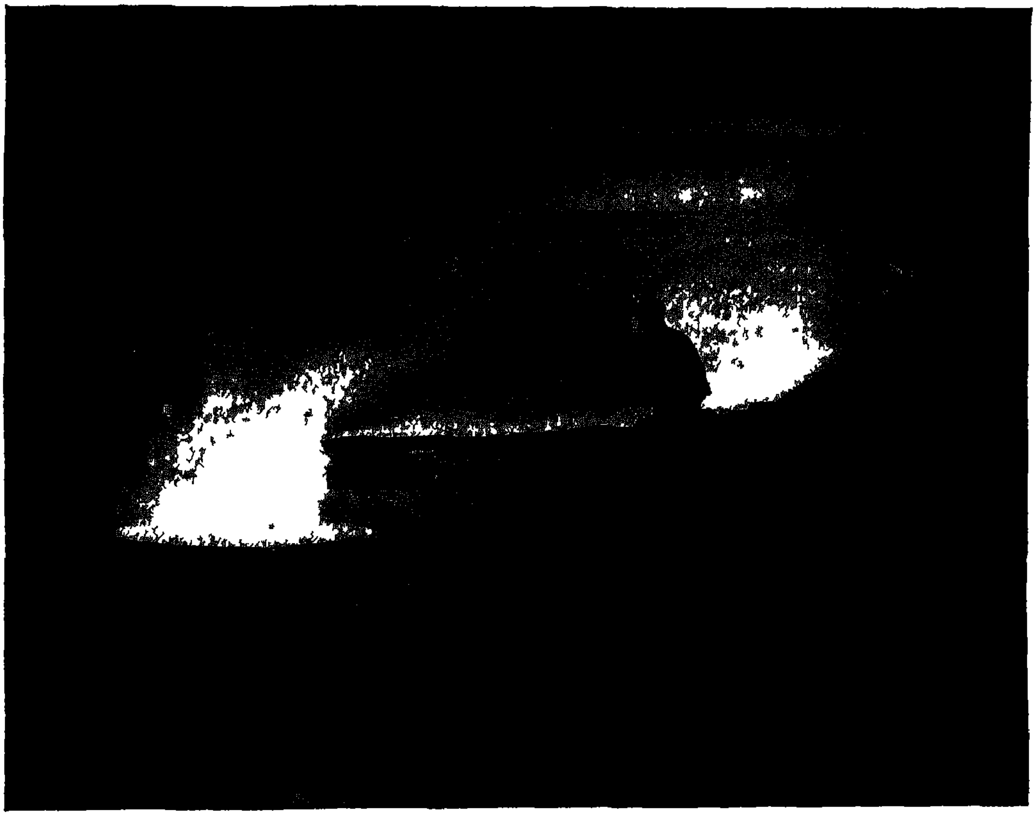
By experience, Man discovered that when the wind was blowing he could obtain a fiercer blaze in his crude hearths for ore-smelting, and a better iron was made. For this reason hill-tops were deliberately chosen for smelting places; but winds are never constant, and in order to obtain the necessary air-draught, devices for converting an open hearth into a crude blast-furnace were invented. The earliest of these was probably the utilization of an inflated goat-skin to act as bellows. Though we tell of such an advance in a few sentences, long centuries intervened between the successive discoveries that gave primitive man a more facile control of this noble metal. And we must imagine a parallel development going on in each cradle of civilization, for such discoveries were but local ones. The rate of growth of the iron industry in later times was far more rapid. In the early years of our era a mass of iron might well be a king's ransom, and in the "Iliad" of Homer it is told that a lump of the metal was one of the prizes in the Greek games. Even as late as the 14th century, in the reign of Edward III, the iron utensils of the royal household were classed among the "jewels."



In the iron-foundry—a fiery cascade of molten metal pouring into moulds preparatory to being drawn into rods or rolled into sheets. A scene at Port Talbot, South Wales

Modern metallurgy is the result of constant experiment and research on the part of chemists and other workers, research that has given the world the wonders of the specialized steels of to-day. Everyone knows that steel is a type of iron with unique qualities of its own. Steels are made by various processes, all of which have for their object the production of a hardened form of iron containing a carefully controlled amount of carbon; the latter varies from 0·1 per cent. in the softer steels to over 2 per cent. in the high-speed steels.

During the last fifty years great advances have been made in the knowledge of the



Turning iron into steel—the initial stage. Vats being filled with molten iron at the Acklam Steel Mills, Middlesbrough

internal structure of steels, partly by chemical analysis and even more by the use of the microscope. When the surface of iron or steel is polished and then carefully "etched" by means of acids, the crystalline formations are revealed. Photo-micrographs are made, and the relation of crystalline forms to physical properties may be studied and invaluable information obtained.

Electrical resistance thermometers to-day enable the manufacturer to regulate and test the temperature of his furnaces. Down to a few years ago furnace temperatures were judged visually by furnacemen, who through long experience could tell approximately by the glow-colour of the molten mass whether it had attained the heat desired.

Steel becomes brittle and hard when heated to a high temperature and then "quenched" by being plunged into cold water or oil. By "tempering" it after this chilling, the hardness or brittleness may be modified to almost any degree desired. This tempering consists in slowly heating the steel to a certain temperature and gradually allowing it to cool. The process is arrested when the colour indicates the required temper, and the tool or spring, or whatever the object may be, is then quenched. When certain alloys are incorporated into the steel, different physical properties are given to the product, rendering it more suitable for specific uses.

For such purposes as the making of high-speed tools that preserve their edge and temper even when friction has made them red hot, these heat-treated alloy steels are absolutely essential. Other steels give that tensile strength so necessary in the parts of engines, of motor-cars, and of other machinery.

Turning with Red-hot Tools

The most used of these alloys are: chromium, which increases the hardness and imparts a brightness; nickel, which gives steel a greater elasticity; cobalt, molybdenum and tungsten, which prevent loss of "temper" at high temperatures; manganese, which increases the toughness of steel; silicon, which renders the steel more acid-resistant; and titanium and vanadium, which help to remove impurities.

Thus, high-speed tools are made from tungsten-chromium steels. Such tool-steels, used for machining and working various grades of other hard steel, are treated by heating the forged tool until its cutting edge is almost at melting point, when the tool is cooled in oil or by an air-blast. The cold tool is later reheated in a lead-bath and again cooled in air. These processes induce such a hardness in the cutting edge that a lathe tool, for example, retains its full utility even when it is machining so fast and cutting so deeply that the edge becomes red hot.

Stainless steel was discovered in 1916 by the English metallurgist, Brearley. Nowadays the designation is used to cover all rustless steels, and not merely the cutlery-steel patented by Brearley. The principal alloying metal is chromium, which usually represents anything from 12 per cent. to 18 per cent. of the steel. But the field of iron-carbon-chromium alloys, containing also various proportions of other metals, is enormous and as yet little explored. Already rustless steels are being put to a thousand uses in industry. These range from the manufacture of trifling but important domestic articles like a potato parer to the recent achievement in England of clothing the bed and banks of a stream with stainless steel plates; the object of this last was to keep the waters in bounds and to afford a channel that would not be choked by silt and vegetation.

It may well be said that although Man has worked iron for some six centuries it is only during the last hundred years that he has really developed the most important uses to which this plentiful metal can be put.

Aluminium and its Alloys

Most of the widely-used metals have been worked by Man for several thousands of years. Thus iron, lead, brass and copper were the metals of the dawn of Western civilization. With these, nations constructed gigantic monuments, and dug great irrigation canals; hewed their way to victory; tilled the soil; hammered out their ornaments and utensils; quarried and built their way laboriously to progress.

Aluminium is not a metal discovered fortuitously but the product of scientific research. Its discovery dates back little more than a century ago (1825), when Hans Christian Oersted by chemical methods obtained a few tiny globules of aluminium. In 1827 Friedrich Wöhler, a German chemist, likewise obtained a small quantity of the new metal. But the process was costly and the production of large quantities was impossible.

Later, Henri Sainte-Claire Deville produced aluminium in France, in slightly larger quantities but on nothing like a commercial scale. It is interesting to remember to-day —when hundreds of tons of aluminium are weekly consigned to the dustbin in the shape of used tooth-paste and shaving tubes, the "lead" foil on tea-packets, the "silver-paper" wrappers round sweets and chocolates, the "tin" foil in cigarette-packets, and in the form of various worn-out kitchen utensils—that only eighty years ago aluminium ranked in price with gold and platinum.

When Aluminium cost as much as Gold

In 1852 aluminium cost £109 per lb.; to-day the same quantity is quoted at 9½d. At the Paris Exposition in 1855, a lump of aluminium occupied a place of honour next to the crown jewels of France. Platinum and aluminium sold for the same price by weight as jewellery. The novelty of the new precious metal was an irresistible attraction. The French Emperor, Napoleon III, entertaining some distinguished guests at a banquet of honour, had aluminium forks and plates set before them as a signal mark of favour; the lesser folk had to be content with plates of mere gold. One minister of state, anxious to present the baby Prince Imperial of France with the most exclusive of presents for his first birthday, gave the royal infant an aluminium rattle.

Even by 1883 the new metal, in spite of all the efforts of chemists to find a cheap commercial method of production, was as rare as silver. In that year, Charles Martin Hall, a student of Oberlin College, Ohio, commenced researches which after three years of patient labour led to his discovery of the electrolytic process—by means of which are produced the vast quantities of aluminium used to-day.

At the time that Hall was experimenting aluminium oxide was quite plentiful, but no chemist had succeeded in evolving a process for producing large quantities of the metal from its oxide. In 1886 Hall made use of cryolite, a mineral found largely in Greenland. This chemical salt in the molten state is capable of dissolving the metallic oxide of aluminium. Cryolite was added to the oxide and melted; an electric current was passed through the bubbling mass, thus "electrolysing" it. On cooling it was dis-

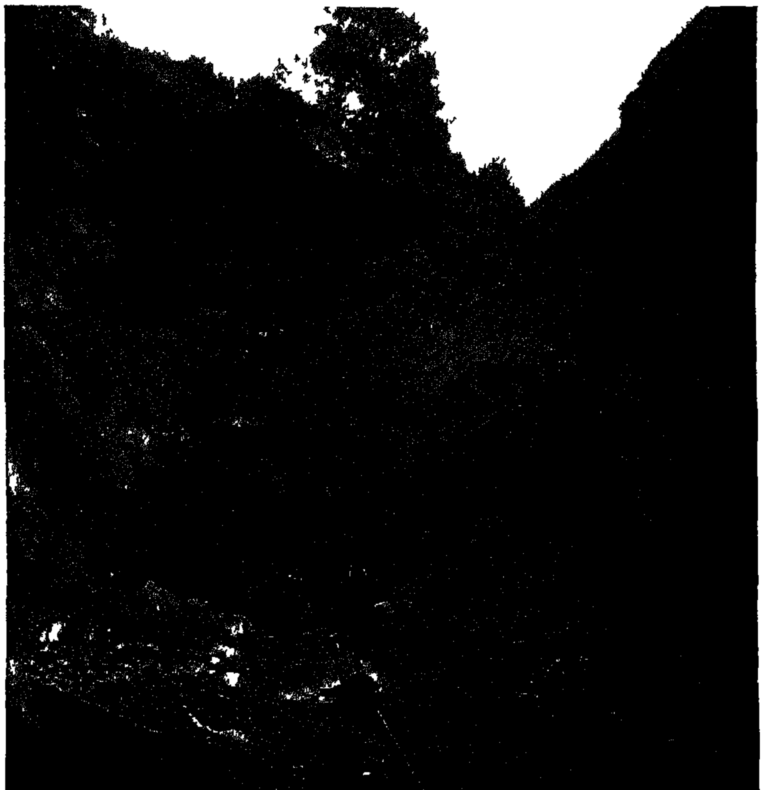
covered that silvery globules of the true metal had been formed. Two months later Paul Héroult, a young experimenter living at Gentilly in France, stumbled upon the same process, although he was entirely unaware of Hall's discovery.

The new method of production was begun on a commercial scale at Pittsburgh in 1888, and the price of aluminium fell so rapidly that in a few years this hitherto expensive metal was being used in almost every home. It is no exaggeration to say that in many industries the advent of cheap aluminium created a minor revolution. The last decade of the 19th century saw the establishment of a great aluminium industry in Britain.

Bauxite—named after Les Baux, the French village where the ore was first discovered and which today produces one-third of the world's supplies —is a high-grade ore from which aluminium is obtained and is comparatively abundant. The greatest sources of bauxite supply, after France, are: Arkansas, U.S.A., which produces one-fifth; Hungary, which produces one-sixth; and British and Dutch Guiana, yielding 9 per cent. and 10 per cent. respectively.

But every handful of clay on the earth's crust contains traces of alumina, the oxide, and there are vast quantities of low-grade aluminous materials such as laterites and high-alumina igneous rocks. Aluminium is in fact the most abundant metallic element in the earth's crust to a depth of ten miles, forming 8·05 per cent. as compared with 5·03 per cent. of iron, the next most abundant metallic element. It must be remembered also that on account of the lightness of aluminium—its density is only 29 per cent. as compared with iron—the actual bulk produced is far greater in comparison with other metals than the quantity by weight might suggest.

It is, of course, on account of its combined strength and lightness that aluminium has advanced so rapidly to its present position as one of the foremost commercial metals. Besides its light weight its other properties are: high thermal and electrical conductivity; pleasing appearance; resistance to corrosion and to certain types of chemical attack; suitability of the metal for use as food containers and cooking utensils; the ease with which aluminium can be wrought.



Courtesy of the British Aluminium Co. Ltd.

Bauxite, the mineral from which aluminium is normally produced, occurs in large deposits in Northern Ireland, Southern France, British and Dutch Guiana, U.S.A. and the Gold Coast. Here is the ore being mined from an outcrop

The pure metal when cast is quite soft and has only moderate strength when wrought cold. But the term aluminium as commonly used denotes not only the pure metal but also its alloys. It is possible by the addition of comparatively small amounts of other elements to produce alloys which retain in a large degree the desired properties of the pure commercial metal. The most commonly used of these "hardeners" are copper, iron, silicon, zinc, manganese and, to a smaller extent, magnesium and nickel. Such hardened alloys are manufactured in large

quantities under careful chemical and temperature control. In effect these various alloys turn aluminium into a score of metals, each with its own unique properties. The development of high-strength aluminium alloys has made the metal available as a structural material in a large variety of forms: sheet, tubing, bar, rod, wire, forgings and structural angle and channel sections. These strong alloys were discovered several years ago when it was found that certain of them, when subjected to appropriate heat-treatment processes, showed remarkable increases in tensile strength and in hardness.

One of the more recent uses to which aluminium has been put is its utilization in cable form for the overhead transmission of electric power. There is good ground for believing that aluminium will oust copper for this use, since pound for pound weight of cable it will carry just as effectively double the current of a copper conductor. For long spans, the aluminium wires are stranded round a core of galvanized steel wires. On a certain power line in Southern California, spanned with aluminium cable, the supporting pylons are located a mile apart, thus effecting a great saving in outlay. It is impossible fully to list the uses of aluminium and its various alloys. Mention has already been made of aluminium foil, for wrapping sweets and various foodstuffs. The domestic uses of the metal are legion, and are being added to every day.

Great engineering schemes owe an increasing debt to this light-weight metal. In the U.S.A. recently, its use for the floor system of a large bridge saved 750 tons of dead-weight, added a computed additional quarter of a century to the life of the structure, and saved the taxpayers £300,000. Every year hundreds of tons of the pure metal are reduced to a flaky powder to provide the pigment for aluminium paint. Giant bridges and ships are more and more utilizing aluminium paint not only for its weather-resisting and durable properties, but also for the great saving in weight as compared with lead paint.

Aluminium in the Air

In aircraft construction, aluminium alloys are greatly used, since they reduce dead-weight without sacrificing structural strength, and are non-combustible and splinter-proof. One remembers, too, that aluminium made possible the construction of the giant dirigibles that are the marvel of the age. The body-work of motor-cars is often of this versatile metal, and that of the coaches of many streamline trains has been made of aluminium sheets on an aluminium framework.

The dairying industry uses aluminium to a large extent. Cheeses are now mostly wrapped in aluminium foil; milk-pails, churns, coolers, and bottling apparatus are in the majority of cases now constructed of the metal, which is unaffected by the various lactic acids. Even the giant milk tanks which travel by road or by rail are being made of the non-corroding metal, and the space between the tank and its outer casing is insulated with sheets of aluminium foil. This latter material has come to the fore also as an insulating material for refrigerators, and even for the treatment of walls.

The fact that all these achievements of aluminium and its alloys have come about in little more than a century, and almost wholly within the fifty-year period of commercial production, is solely due to the tireless research and inspired genius of the chemist, who has presented these new and wonderful gifts to mankind.

The Discovery of Uranium

Although pitchblende deposits have been worked in Bohemia since 1517, the epoch-making isolation of the metallic element radium did not occur until as recently as 1898. Pitchblende, or uranium oxide, is a bluish-black, heavy mineral found in igneous rocks, and possesses a pitch-like lustre, from which fact its name is derived. In 1789 the German chemist Klaproth isolated from it a lustrous white metal which he named uranium, in honour of Herschel's discovery of the planet Uranus, eight years earlier.

The French physicist Henri Becquerel discovered in 1896 that minerals containing uranium gave off rays very similar to the X-rays discovered by Röntgen in the previous year. These uranium-rays were capable of traversing wood, paper and the less dense metals such as aluminium. Soon after this discovery of the radio-active properties of uranium, scientists had reason to believe that the metal itself contained hitherto unsuspected substances.

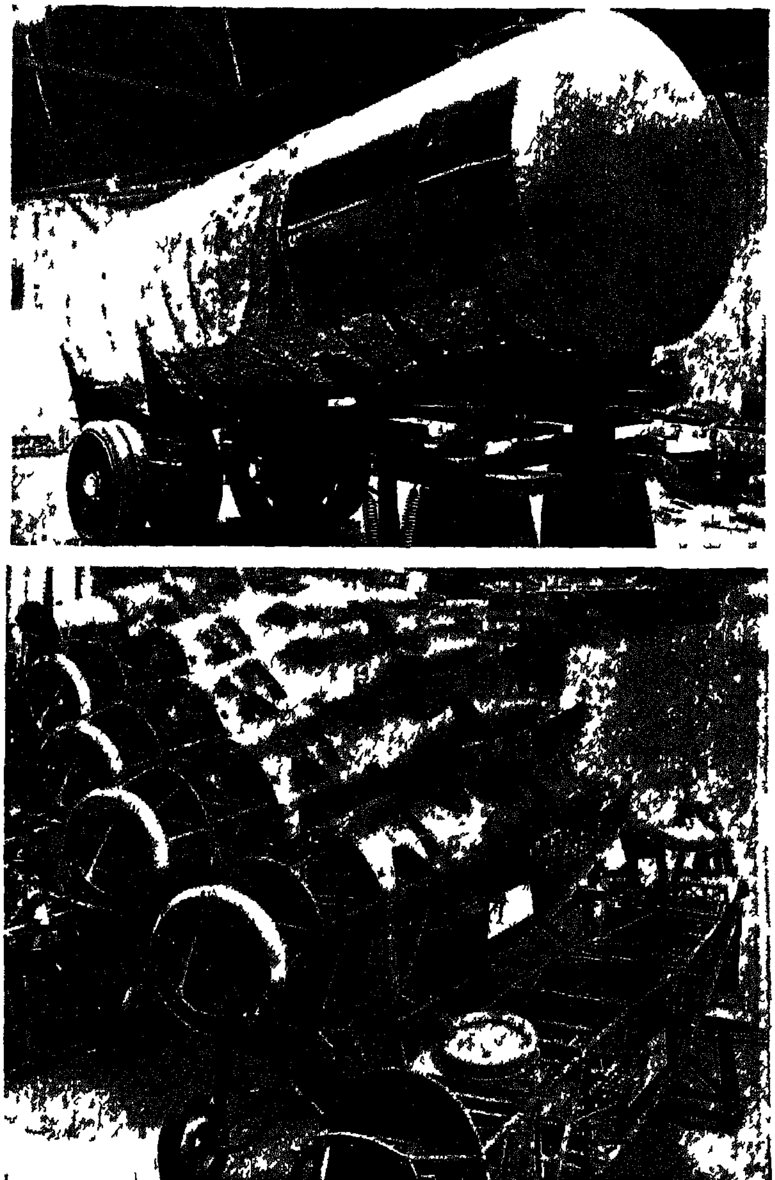
The honour of the discovery of the more important of these substances contained in uranium belongs primarily to Madame Marie Curie. She was born in Warsaw, Poland, in 1867. Even as a young girl she showed an intense interest in science, and though very poor, she determined to go to Paris in order to complete her scientific education.

During her course of studies at the Sorbonne, she became the pupil of Pierre Curie, the physics professor. Tutor and pupil formed a friendship that ripened into love, and were married in 1895.

A Partnership that produced Radium

Professor and Madame Curie shortly after their marriage devoted themselves to attempting to discover the unknown active substance present in pitchblende. A specimen of that mineral, possessing two-and-a-half times the radio-activity of uranium, was chemically examined by them in 1898. Ultimately a new element was discovered which was named Polonium in honour of Madame Curie's native country. Over a ton of pitchblende residues was then dealt with and separated into different components. It was found that the barium sulphate isolated from the pitchblende was particularly radio-active. After chemically treating the barium sulphate, a tiny quantity of a new compound was discovered —a metallic bromide that was found to be a million times as active as uranium. The parent element of this unique bromide was named radium.

The quantity of radium in existence is very small and its preparation from pitchblende is not the only method that yields the wonderful metal. A certain amount of radium has been produced in the U.S.A. from carnotite, a yellow mineral mined for both the metals uranium and vanadium; radium has also been extracted from autunite, a phosphate of uranium and calcium mined in Portugal. Usually, however, pitchblende yields higher returns of radium than these other sources of supply. Yet ten tons of pitchblende yield only the infinitesimal quantity of one gram of pure radium. So valuable is radium, indeed, that mines of carnotite and autunite



Courtesy of the Westland Aircraft Works, and (top) Alfol Insulation Ltd

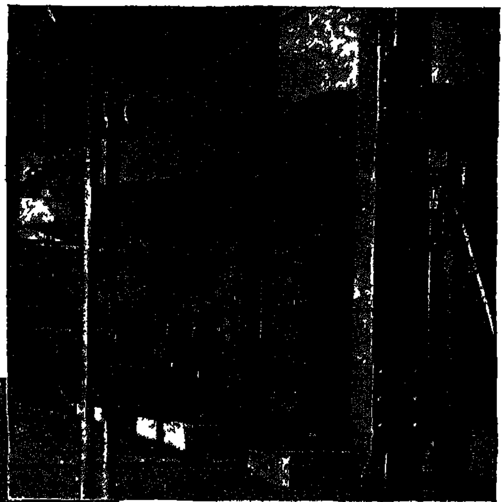
Eighty years ago aluminium was one of the most precious of metals, costing over £100 for 1 lb To-day it is among the foremost commercial metals and its uses are legion. In aircraft construction its essential quality of lightness makes it invaluable. Aeroplane fuselages built almost entirely of aluminium and light alloys and (*top*) a 2,000 gallon milk transport tank being insulated with aluminium foil

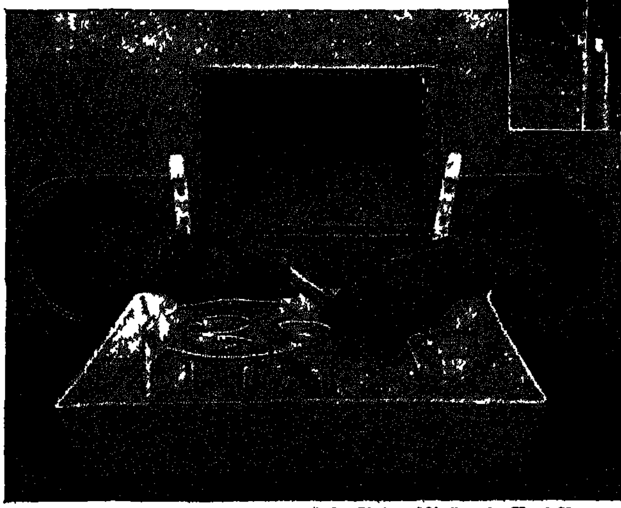
Courtesy of the Union Minière du Haut Katanga

Producing the rarest metal in the world, a ton of which would be worth £10,000,000,000. One of the principal sources of radium supply is the Belgian Congo Pitchblende, silicates and aluminates of uranium are obtained from the Chinkolobwe mine, Haut Katanga (*top*), and transported to a factory at Oolen, near Antwerp (*bottom*), where the metal is extracted.
(*See also illustrations, p. 391*)

yielding only one gramme of the rare element for every 200 tons of mineral mined and treated, are considered worth-while propositions.

On May 25, 1921, at the National Museum in Washington, Madame Curie was presented with ono gramme of radium bromide. Five hundred tons of Colorado carnotite had been treated in order to secure this minute quantity, to purchase which the women of America had raised the money by public subscription. The price of radium in the past has varied from £20,000 to £25,000 per gramme, but with the discovery of new fields of pitchblende the price now has been lowered to something less than half the larger figure. The chief sources of radium supply are the U.S.A., Czechoslovakia, the Belgian Congo, Germany and Cornwall. It is estimated that there is little more than 1 lb. of recovered radium in the whole world. A ton of the world's rarest metal would be worth about £10,000,000,000.





Courtesy of the Union Minière du Haut Katanga

Stages in the production of radium at the Oolen factory. *Top:* Reaction vats through which the radium passes during the process of segregating it from silica and (*bottom*) opening tubes containing salts of radium content preparatory to precipitation of the radium.
(*See also illustrations, p. 390*)

A specimen of radium has the appearance of a few grains of common salt, which are, however, luminous. One of radium's most striking properties is the power it possesses of exciting phosphorescence in other substances brought near it.

It is outside the scope of this story to explore the vast field of radio-activity and the many other discoveries in pure and applied physics made possible by the wonderful work of the Curies. It is sufficient to say that with the discovery of radium, the whole world of science took a great step forward. In fields of use as remote from one another as atomic research and the cure of malignant disease, the radioactive element has opened up new possibilities. Thousands of sufferers, either cured or eased of their pain by radium therapy, must have reason to bless the gift which the research of the Curies brought to them.

We are in the age of synthetics. Let us quote a few examples of substances the chemist has "created." For thousands of years natural silk has been woven into delicate fabrics by Man. Of recent years the chemists have given us synthetic silks, one form of which is often referred to as "rayon." For centuries in the East the soya-bean has been cultivated as an article of food. Mr. Henry Ford, of automobile fame, has recently erected at the River Rouge works, at a cost of nearly a million pounds, a gigantic mill for processing soya-beans into plastics, from which are moulded automobile parts.

At a factory run by Dr. Bergius, an eminent German chemist, white sugar is being made from sawdust and wood-waste. An American scientist has produced his three-hundredth invention for utilizing the pea-nut, which amongst other things he could already turn into commercial tooth-paste, "chocolates," boot-polish and synthetic "milk." One could go on endlessly listing the strange uses to which apparently very ordinary pro-

ducts are put, once they have passed through the hands of the chemists.

Wonderful Colours from Coal-tar

Perhaps in no other field has chemistry achieved such remarkable results, affecting the life of the average citizen, as in more or less recent discoveries of synthetic dyes. But the thousands of dye shades that we revel in to-day have only recently become available. The more obvious use of dyes is to colour textiles, but actually dye-stuffs play a far larger part in modern civilization than that. Few materials of everyday use, if presented in their natural colourless state, would appear very attractive. So the modern manufacturer has taken advantage of the wonderful gift of the synthetic dyes which the chemist has placed at his disposal. To even the most ordinary and humdrum articles he gives allure by varied colouring.

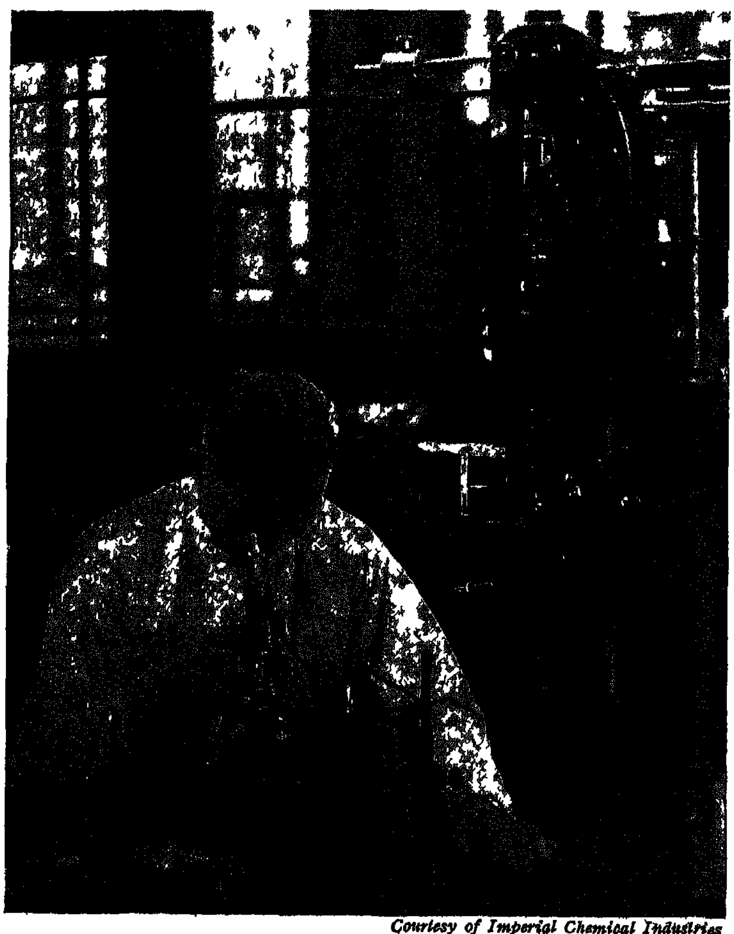
The ancient peoples of Egypt, India, China and Persia to a limited extent dyed by hand the fabrics which they manufactured. But their colour materials or dye-stuffs were very few and were obtained directly from Nature. Perhaps the most ancient of all dyes were the red obtained from the madder plant and the blue obtained from the indigo. Further dyes were made by utilizing coloured earths—red from earths containing ferric oxide, and yellows from yellow clays. A few centuries before the Christian era the Phœnicians were dyeing stuffs with the famous Tyrian purple, the pigment being got from a sea mollusc found along their coasts.

The art of dyeing with such natural dyes as these was rapidly gaining ground when the scourge of barbarian invasion fell upon the western world, and for long thereafter science and culture languished. In the 13th century A.D. the first revival in the art of dyeing took place. In 1429, at Vienna, the first European book on dye-stuffs was published. In 1472 a Dyers' Company was incorporated in London.

The discovery of America and the finding of a sea route to the East Indies introduced new dye-stuffs to Europe; thus colouring matters were obtained from a number of dye-woods such as logwood, which yielded a purple dye. But it was not until the middle of the 19th century that the possibility of obtaining dye from coal-tar was considered.

It was in 1856 that W. H. Perkin (later Sir William Perkin), an English chemist, obtained a violet dye from aniline, itself a derivative of benzene, which in turn is obtained from coal-tar.

The discovery of the first coal-tar dye heralded the discontinuance of most of the

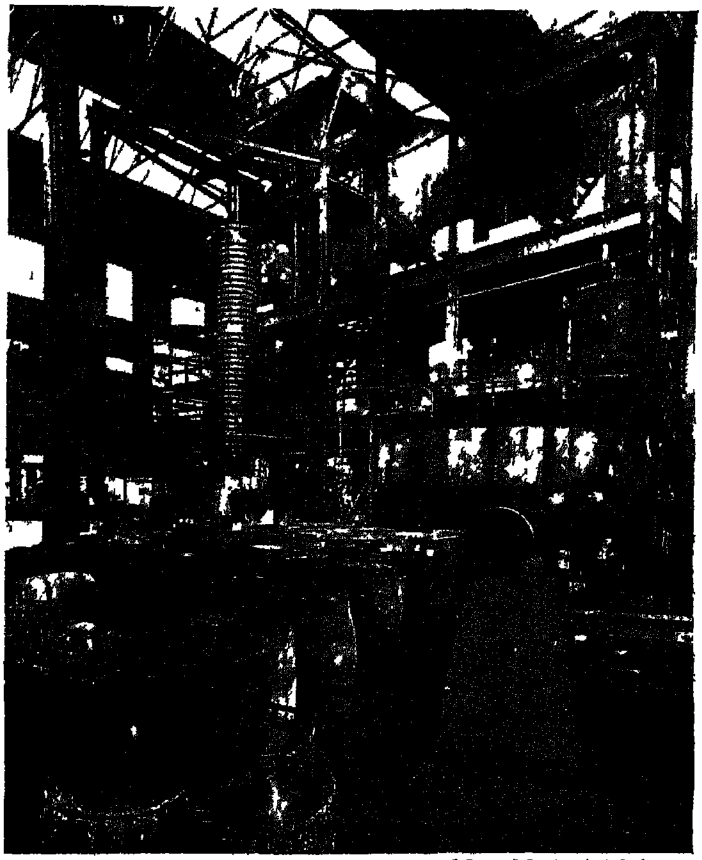


Courtesy of Imperial Chemical Industries

The wonderful range of brilliant colours which the modern manufacturer has at his disposal is the result of years of patient work by the chemist. Research goes on continually in the dye-stuffs industry and all manner of tests relative to durability, resistance to weather, etc., are carried out. Here a chemist is conducting a microscopic examination of varnish film after it has been subjected to accelerated weathering

vegetable dyes hitherto used. The vast madder fields of France, which produced the dye known as Turkey red, were soon no more. The indigo trade struggled valiantly against synthetic dye competition; but although nearly a million acres of indigo were grown in India as recently as 1897, most of the "indigo" dye now used is produced from the coal-tar constituent naphthalene, familiar to us in the shape of moth balls.

Once Perkin had opened the door to the discovery of coal-tar dyes, scores of new synthetic colours were rapidly put on the market. Coming to the somewhat drab Victorian Age—some seventy years ago—these brilliant colours which we now accept as quite ordinary were a source of wonder and novelty. In the International Exhibition held in London in 1862 as much interest and excitement was manifested by the crowds constantly surrounding the new coal-tar dye exhibits as was ever shown by those that had clustered about the fabulous Koh-i-noor diamond in 1851.



Courtesy of Imperial Chemical Industries

Though at one time Great Britain lost her leading position in the dye-stuffs industry, it is now on a thriving basis in this country. Vats and containers in a dye-stuffs works at Blackley, Manchester

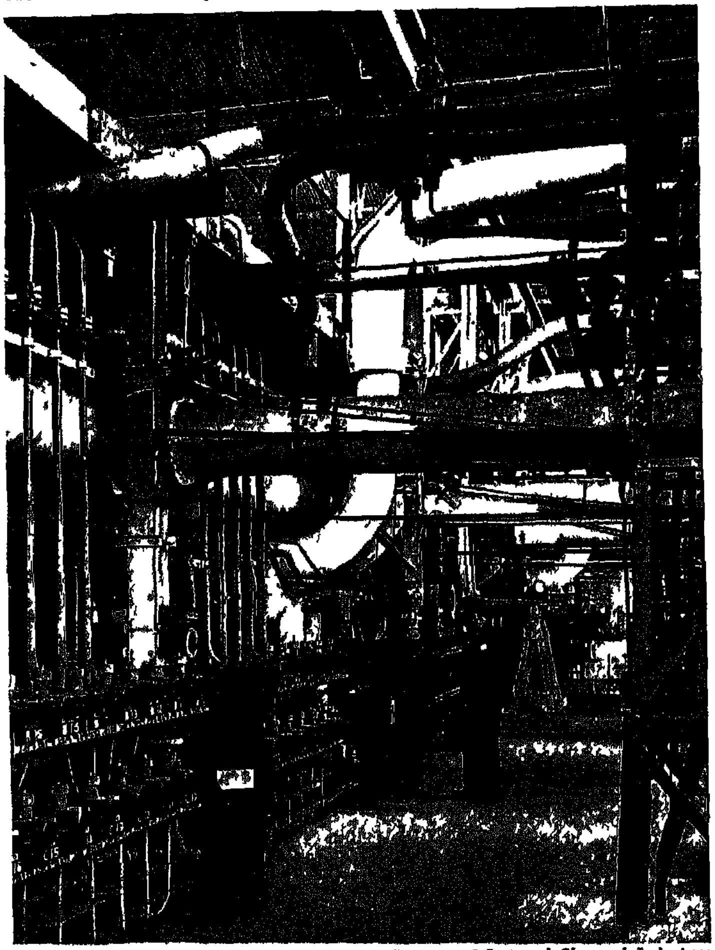
It is interesting to note which were these earlier dyes. The great majority were made from aniline—for example, magenta (aniline red), aniline yellows and blues. To-day, for every synthetic process of dye-extraction known in 1862, there are sixty now available. But although England opened up the field to these discoveries and bore away the honours in the 1862 Exhibition, she soon lost pride of place. German chemists and manufacturers spent half a century in building up a great dye industry with which, when the Great War broke out in 1914, they had almost a world monopoly.

Dyes Delivered by Submarine

Nations previously dependent on Germany for their dyes had then to make use of poor substitutes. In 1915 a single keg of German dye, which in early 1914 had sold in the U.S.A. for £3, was eagerly purchased for £300. Laden with cargoes of aniline dyes valued at an enormous sum, the German submarine *Deutschland* dived under the Allied mine-fields to deliver her precious cargoes at some rendezvous previously arranged with the neutral purchaser. But most of the great countries of the world, thus forced to rely upon their own resources, rose to the occasion and created independent dye industries of their own.

In the days of our grandfathers, crude coal-tar, a black, sticky and malodorous liquid, was regarded as useless and burned as waste. To-day, besides serving as the basic substance for dyes of all hues, that "waste material" is turned into drugs, disinfectants, anaesthetics, perfumes and petrol. At the gas-works, coal-gas is of course the primary object of manufacture. Coal is heated strongly in the closed retorts and yields four main products: gas, tar, coke, and a watery ammoniacal liquid. The average yield of coal-tar is ten gallons per ton of coal, or 5 per cent. by weight. Several

hundred chemical constituents have been identified in coal-tar but only about a hundred have been isolated, and of this hundred only a few have so far been used commercially. Naphthalene, already referred to, is the predominant constituent, often representing as much as 10 per cent. of the crude tar. Nearly all synthetic dyes are made either from naphthalene or from one of four other hydrocarbons found in coal-tar—benzene, toluene, xylene, and anthracene.



Courtesy of Imperial Chemical Industries

Suggestive of the advanced stage reached by the petrol from coal industry in Great Britain—control instruments and valves at the Billingham plant

From these crude hydrocarbons are obtained over three hundred "intermediates"; from the intermediates some one thousand dyes are produced; and from these main dyes, several thousand others. Besides being found in the coal-tar extracted when the coal is heated, the more volatile hydrocarbons—benzene and toluene—are contained also in considerable quantity in the crude coal-gas. When a housewife turns on a gas-tap at her stove the gas itself, although heard, is invisible; but if one tries the experiment of heating a little coal in a clay pipe pushed into the fire, the gaseous *mixture that issues* from the stem is a clearly visible, smoky one. The reason is that before it reaches the gas-holders the gas has been cleaned by being washed with high-boiling solvents. Thus the gas is freed from its benzene and toluene, together with certain impurities. When these latter are removed, the hydrocarbons are utilized commercially, being converted by chemical processes into explosives or into a number of lovely and brilliant dyes.

These chemical processes are often highly involved. As a simple example we may instance that used by the discoverer of mauve. Perkins obtained mauve by adding potassium dichromate to a solution of aniline (derived from coal-tar benzene) in dilute sulphuric acid, whereby a black precipitate was formed. This, after removal of impurities, was dissolved in alcohol, in which it formed a rich purple-coloured solution. Research is a never-ceasing process, and months, or even years, of what to an outsider may appear fruitless work goes to the pursuit of an elusive object. By such tireless effort were discovered or evolved the beautiful dyes which are now put to everyday use. In a happily worded phrase it has been said that "The chemist puts his hand into the black mass—coal-tar—and draws out all the colours of the rainbow."

The countries of the western portion of Europe, though endowed with coal measures, have little or no natural supplies of fuel oils. The invention of the internal combustion engine, with the advent of the motor vehicle, produced a rapidly increasing demand for oil and petrol. Then, too, the fact that in

Courtesy of Imperial Chemical Industries

The problem of extracting petrol in commercial quantities from coal has been tackled by the British chemist with courage and tenacity. Already great progress has been made and to-day the vital fuel is produced in this way regularly if in relatively small quantities. Here are the high-pressure vessels at Billingham in which the coal is hydrogenated

certain other forms of transport coal has been superseded by the easier-handled liquid fuels has rendered such oil-lacking countries anxious to convert their coal supplies into liquid fuel. This, of course, is possible only by the application of chemical methods. Coal contains variable but appreciable proportions of the hydrocarbons that compose the liquid fuels distilled from petroleum, but in coal the ratio of hydrogen to carbon is very much lower than in the petroleum products. To obtain liquid fuels comparable to those derived from petroleum, the hydrogen-to-carbon ratio in coal has to be increased.

For many years chemists have grappled with this problem, and numerous methods have been developed to solve it. The most promising of these is the direct treatment of coal with hydrogen under high pressure and at high temperature. This process was evolved as long ago as 1914, by the German chemist Bergius, to whom reference has already been made. Bergius's

process, known as the hydrogenation process, was utilized in 1924 to test the suitability of British coals for the extraction of synthetic petrol. Although great progress has been made since then, the quantities of synthetic petrol produced at present by the hydrogenation process are still small.

The procedure is usually as follows: coal is placed in a sealed converter heated by an electrical furnace. Compressed hydrogen is admitted. The converter is then heated to "reaction temperature" and maintained at this for about an hour, after which it is allowed to cool. The light spirit recovered by distillation is then refined for use as commercial petrol.

Extracting Benzole from Coal-gas

An entirely different type of process for the production of liquid fuel from coal is that in use at the Beckton, East London, works of the Gas Light and Coke Company. Here is the largest benzole recovery plant in the world embodying the adsorption principle, with a daily output of some 16,000 gallons of benzole. The adsorption principle lies in the utilizing of activated carbon to adsorb the hydrocarbon vapours from coal-gas. When the carbon is, as it were, fully charged with these vapours, the adsorbed compounds are expelled with the aid of steam. At the first adsorption the carbon takes in benzole from the coal-gas up to one-fifth of its own weight. When incapable of further work the carbon is removed and heated in a furnace to fit it for further use. Coal-gas contains on an average three-and-a-quarter gallons of benzole for every ton of coal carbonized in the retorts.

There seems little doubt that the science of making synthetic fuel oils is as yet only in its infancy. At the present rate of consumption there is a prospect that the known supplies of natural liquid fuel may be exhausted within the next century or so. Only through the researches of the chemist in the field of synthetics, therefore, can the world hope to be ensured of adequate supplies of these greatly needed sources of motive power.

CHAPTER XXIX
WHEN THE EARTH TREMBLES

SEISMOLOGY, the study of earth tremors and earthquakes, is one of the youngest of sciences. When our early ancestors experienced earthquake catastrophes they believed these terrifying visitations to be the outcome of the wrath of gods and demons. From the time civilized mankind began to regard such a belief as a primitive superstition, succeeding generations have put forward one theory after another to explain how and why the earth trembles.

Such a famous Greek as Aristotle and such eminent Roman writers as Seneca and Pliny the Younger all found a place in their works for that awe-inspiring phenomenon—the earthquake. It was only reasonable that earthquakes should claim their interest, for the areas of greatest seismic activity in Europe were to be found in Greece and Italy.

But it was not until the mid-eighteenth century—after the severe Lisbon earthquake of 1775—that John Michell, a Cambridge Professor of Geology, wrote his well-known memoir on earthquakes, in which, for the first time, the subject was dealt with scientifically. Michell put forward several new theories in regard to the origin of these great tremors, and was the first to attribute the vibratory movement in earthquakes to elastic waves passing through the earth's crust.

How these waves first come into being is still an unsolved problem. Every group of seismologists, geologists, and even astronomers has its own explanation. A study of the theories regarding the dreadful earthquake at San Francisco in 1906 illustrates the great divergence of opinion.

When Seismologists Differ

The calculations of Professor Reed, who was in charge of the seismometer, or earthquake-recording machine, at Victoria, British Columbia, led him to assert that the main seat of the earthquake was somewhere on the sea bed of the Pacific Ocean. Professor Matteucci, director of the Vesuvius observatory in Italy, many thousands of miles from the scene of the calamity, had quite other views. He wrote: "Notwithstanding the distance separating Vesuvius and the Californian earthquake, I believe a close relation exists between the two phenomena, which I consider as different effects of a common cause." Yet a third opinion came from the famous French astronomer, Abbé Moreux. He believed that the sun had a certain influence on the earth, much as the moon

has on the ocean, and that a rapid increase or decrease of solar activity caused fresh outbursts of seismic disturbance. Such a cycle of events, he suggested, occurred every twelve years. The Abbé pointed to the great increase in seismic activity during the previous six months, when the sun, too, had been unusually active.

But, whatever the underlying cause, the result of the disaster at San Francisco in that April of 1906 was appalling. Not only was the city itself entirely wrecked, but the earth movement extended along a remarkable underground fault or rift some 270 miles long. Houses and villages lying as far away as 25 miles from the direct path of the disaster were shifted horizontally, and field fences were found standing as much as fifteen feet from their original position.

Buildings in Los Angeles, some 300 miles away, rocked violently; many houses fell at Sacramento, eighty miles distant, killing a great number of people; and along San Francisco Bay three miles of railway track sank from sight. Buildings at Salinas, 100 miles to the south, were wrecked, while 1,000 people were killed at Santa Rosa, a nearby Californian beauty spot.

San Francisco, April 18, 1906

The first shock caught the city of San Francisco at 1.15 a.m., when the majority of its 400,000 inhabitants were sleeping peacefully. From swaying hotel and rocking shack rushed swarms of terror-stricken people, clad only in their night-clothes. In many streets the pavements had vanished, leaving yawning gaps to catch the unwary. A few minutes later another convulsion shook the city. Buildings which had partly withstood the first throes now swayed dizzily before crashing on the hapless throngs in the streets below. Tramcar tracks were twisted into knots.

One curious feature of this earthquake was the extreme irregularity of its course. In the wharf district the frameworks of the great gas reservoirs were wrenched into the most fantastic shapes, and enormous factories were thrown to the ground. Yet only a few yards away wooden shacks had scarcely a board out of place.

Devastating as the convulsions had been, infinitely greater damage was done by the simultaneous fires which broke out immediately afterwards. Gas and water mains had all burst, increasing the danger and damage a hundredfold. There was nothing to do but blow up buildings in the paths of the flames. Whole blocks were demolished. But faster than firemen and engineers could work, the blaze, fanned by a strong breeze from the sea, spread through the city. A second big shock came soon after dawn, and the panic of the population was indescribable.

Throughout the day and ensuing night thousands of the homeless fled to the hills beyond the town, where milder shocks still continued to be felt. A thousand troops from nearby towns were hurried in response to calls for aid. Millionaires were reduced to a level with the poorest.

Food supplies were running short and mobs everywhere becoming desperate. Next day ships and lorries began to arrive with tents, food, clothing and medical supplies. Railways carried relief goods free of charge. Within six days facilities for feeding the destitute were in full working order. Insurance companies paid out £60,000,000 in claims, and the census showed that 28,188 buildings, valued at £21,000,000, were irreparably destroyed. The number of dead could only be roughly estimated. Over 1,000 bodies were recovered; but another 4,000 missing were never traced. The number injured totalled tens of thousands.

Yet within a month the city resembled an ant-hill, bustling with activity; and soon the gaunt ruins gave place to the newer and grander San Francisco of to-day.

Secrets Revealed by Seismology

The science of seismology, in its short existence, has revealed some amazing secrets of how the earth is built, of how its crust is constantly moving, and even of what substances it is composed. One of the greatest aids to this knowledge is that wonderfully accurate piece of mechanism, the seismometer. It is perhaps the most accurate measuring instrument which man has yet produced.

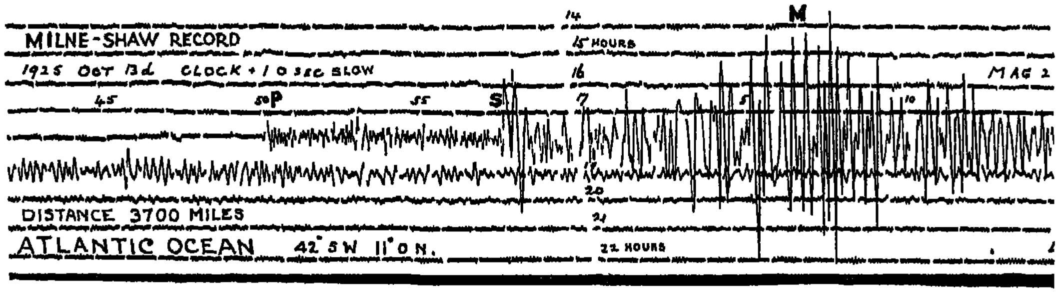
As early as A.D. 132 a Chinese scholar, Chang Heng, invented a simple earthquake detector consisting of a wooden rod so suspended that it could move in any one of eight directions. A ball was held lightly along each of these lines, and when thrown down by the rod was caught in a cup below and so revealed the direction of the tremor.

In the nineteenth century an entirely different, though still simple, type of earthquake recorder was erected at Comrie, in Perthshire, where many earth tremors have been experienced. The British Association in 1872 built a small stone earthquake house here. It had a rock floor, sprinkled over with sand. On this lay two boards at right angles,

to each other. On each board were balanced nine wooden pins varying in thickness. According to the strength of the shock, different sized pins fell, and the direction of the fall showed the direction of the tremor

The modern seismometer proper began with the inverted-pendulum type, invented by Professor J D. Forbes in 1841 and erected near Comrie. The essential feature of any seismometer is that some member within it shall remain at rest, or as nearly at rest as possible, during the complicated movements of the ground in an earthquake. From this stationary member swings a rod which does respond to earth vibrations. It has at its end a point or pencil which, as the rod vibrates to the tremors, records the movements on a sheet of paper.

The seismometer most in use nowadays is the Milne-Shaw type with a horizontal rod or pendulum. The record of movements is made by photographing the path of a spot of light on sensitized paper revolving on a drum. The pendulum at its outer end is coupled to and rotates a small mirror. A beam of light is directed on to the mirror and reflected back to the recording drum bearing the sensitized paper. If the pendulum is still and the mirror therefore steady, a straight line is shown on the drum; but when earth tremors occur the pendulum vibrates and with it the mirror, so that a zigzag line is produced on the record, as shown in our illustration. The Japanese "Omori" type of seismometer uses the same principle, but the record of tremors is made on smoked paper.



Courtesy of Mr J J Shaw of the British Association Seismological Committee

The Milne-Shaw seismograph with covers removed and principal parts named. 1. Pendulum. 2. Mirror. 3. Weight. 4. Suspending wire. 5. Magnets for damping. 6. Recording drum. 7. Lamp to supply light ray. 8. Driving clock. Top: Seismogram recorded at West Bromwich of an earthquake which occurred in the bed of the Atlantic Ocean, 3,700 miles away. (*See text for full explanation*)

But as there are two kinds of earthquakes, two types of instrument are necessary. There is the horizontal earthquake in which the movement is sideways, and the vertical earthquake in which the crust moves up and down. The seismometers so far mentioned are for registering horizontal vibrations. There is another, built on the principle introduced by Professor T. Gray, which records vertical movements.

There are times, however, when even the best seismometers cannot fully register the shocks of an earthquake. If the earth vibrations are too violent, the delicate needle or point of light is thrown violently off the registering band of paper. This happened at the Laibach Observatory in Yugoslavia early on the morning of December 28, 1908. Only one of the twelve seismometers was able to measure a series of violent shocks which were calculated to have their centre (scientifically the "epicentre") in Sicily. Later news proved this calculation correct. Even as far away as Ekaterinburg, in Russia, a seismometer recorded that the town was directly in the area disturbed by this same powerful under-earth wave.

Here again, as in the San Francisco earthquake, scientists hotly disagreed as to the cause of the earthquake. M. Stelling, the Russian secretary of the International Seismic Commission, maintained that the suddenness and extent of the vibrations pointed to the earthquake as being of volcanic origin rather than to a fracture or shrinking of the earth's crust. Dr. Suess, another eminent seismologist, believed that Sicily lay on the edge of a great earth fracture. The earth's crust, he maintained, is here sinking seaward to the north-east, and is permanently unstable. The Abbé Moreux's theory of solar activity influencing earth movements seemed to be supported by the Sicilian disaster.

The Messina Earthquake of 1908

Messina was the centre of the tragedy. With tall, white buildings which followed the sweep of the bay, the city appeared on that December morning a picture of peace. A few very early risers were stirring, but most of the 150,000 inhabitants slept soundly. Then, without the slightest discernible warning, the land seemed to be turned to a plastic and houses tossed on the waves like ships at sea. Within thirty seconds, two-thirds of the city had crashed in ruins, burying nearly half the population. The great height of the buildings and the narrowness of the staircases made the town a gigantic death-trap. Yet some miraculous escapes were recorded.

When the Hotel Trinacria collapsed, a Signor Birgot, occupying a room near the top of the house, was flung from his bed. Scarcely had he risen to his feet when he was hurled into the air and the roof crashed down upon him. Recovering consciousness, he found himself a prisoner in a nook so small that he could not move a finger. With his teeth he tore a hole in some cloth that lay over his face and called for help. He was rescued none the worse for his adventure.

A group of English and Swedish people found themselves marooned three floors high. Most of the lower part of the hotel had gone, and there was only one wall to support the remaining upper floor. Fortunately, all eventually saved themselves by scrambling down a rope of knotted sheets.

Great Loss of Life

The beautiful cathedral, pride of Messina, became a mound of debris. The docks and harbour works sank to sea-level, and the lower-lying parts of the town were submerged under twenty feet of water. Hundreds of soldiers were killed by the falling debris when the barracks collapsed, and under the ruins of the station the bodies of forty railway employees were later discovered; 650 convicts escaped when the prison fell.

In the harbour a huge seismic wave swamped the smaller ships and rushed into the town, adding to the already vast number of victims. Farther along the coast the wave did still greater damage. Rising like a great wall thirty feet high, it surged inland, sweeping away hundreds of houses. The railway line at one part completely vanished, while whole seaside villages were entirely obliterated. It was estimated that 2,000 people lost their lives at Palmi and Sant' Eufemia, and at Catania several vessels went down with all hands.

The town of Reggio, situated on the mainland and some ten miles from Messina, was razed to the ground. Hospitals, houses, castles, schools, were hurled into one great mound of debris. As the buildings collapsed, enormous waves came rushing inland to complete the destruction. Twenty thousand inhabitants of the stricken city lay dead.

Rain came, fortunately, to extinguish the fires that had broken out in various places. Since there was no shelter to be found for the women and children and the injured, many of them were taken on board the rescue ships until the supply of tents and provisions was adequate. The question of dealing with the countless corpses was urgent. Identification

in most cases was impossible, and there was no time to dig graves in the bitter cold and hail that followed. So the bodies of the victims were taken out to sea for mass burial.

Three Types of Earthquake

Scientists have for some time clearly differentiated between three types—volcanic, tectonic, and bathyseisms.

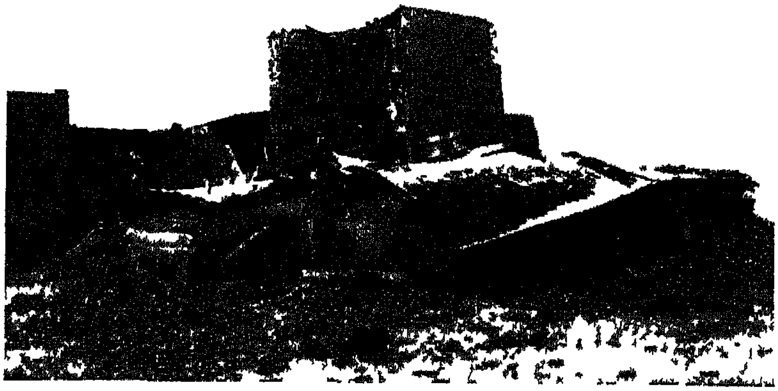


Photo: American Colony, Jerusalem

Earthquake effects in two hemispheres. Deep fissures near the Dead Sea caused by the Palestine earthquake of July 11, 1927, in which the town of Nablus was ruined. *Top:* Remains of a college at Helena, Montana, U.S.A., wrecked during a series of 564 tremors experienced in the State in November, 1935

The term volcanic earthquake almost explains itself. Cataclysms of this kind occur in close proximity to volcanoes, and usually precede and follow a volcanic eruption. The area they disturb is comparatively small—seldom more than 150 square miles—for the eruption of a volcano affects only the under layers of earth in its immediate vicinity. Lava, rising inside the volcano, forces its way into cracks in these layers, and the pressure of the lava is so great that it causes an upheaval of the earth above. These shocks precede a volcanic eruption. Earthquakes following the eruption are usually caused by the slipping of rock adjoining a fracture, in the settling down process after the volcanic outburst has ceased.

Tectonic earthquakes are the most numerous of the three forms, and are due to the formation and development of subterranean faults. The fracturing of the rocks may start many miles below the point on the earth's surface where the disturbance is most felt. This starting-point is called the focus, and the point on the earth's crust where the vibrations emerge is the epicentre. Tectonic areas are to be found in those parts of the world where mountain building has most recently taken place. That is why earthquakes in the Pacific regions, where the mountains are geologically more recent, are more frequent and dangerous than those occurring around older formations

Desolation and destruction wrought by the great Japanese earthquake of 1923, in which 125,000 persons were killed. The Nihombashi ruins and (*top*) tangled tramway wires in a devastated area in Tokio

bordering the Atlantic. According to one eminent geologist, the late Professor J. Joly, the earth's crust is now as reposeful as it will ever be. Beneath it is a layer or substratum so charged with radio-active energy that the earth can never be wholly at rest.

The bathyseism, a more recently differentiated type of earthquake, has its focus at a tremendous depth below the surface. This depth is variously given as 125 to 375 miles, and may be much more. The Assam earthquake of 1897 spread over such a vast area and had such widely scattered movements that it was probably due to a bathyseismic displacement; since the deeper the focal point of the disturbance, the wider is the area affected at the top. Some of these bathyseismic earthquakes are so deep-seated that their effects are never felt on the earth's surface except by the delicate recording needle of the seismometer.

According to a widely held theory, the earth consists of a vast fluid core on which floats the outer crust of the continents and the land beneath the oceans. This theory has grown out of the evidence of the waves set up by earthquake shocks. Different waves travel at different speeds through the earth's crust, according to the kind of rock or fluid through which they have to pass. Certain of the secondary waves seem to disappear, never to emerge again or be recorded on distant seismometers. This would occur if and when such waves encountered a fluid medium: hence arises the theory that the earth's core is fluid. Other investigators go further and say that this fluid is molten iron which lies about 1,700 miles below the outer surface of the earth. Several variations of this theory are being investigated with the aid of information given by the behaviour of the earthquake waves.

Another suggestion put forward is that the continents float on an under-world ocean of molten basalt, a dense rock substance of which most great lava flows are composed. Deep-seated earthquakes—the bathyseisms—very probably have their origin in the constant readjustments going on either in this mass or in the earth's core itself.

Fifteen Thousand Square Miles of Horror

In the great Tokio disaster of 1923 the depth of the focus of the disturbance was calculated to be thirty miles underground, and its epicentre out in the ocean. Stupendous as was the loss of life and property at Tokio and Yokohama, it would have been far worse if the epicentre of the earthquake had been situated beneath Tokio itself. As it was, the epicentre was many miles distant, under the sea-bed in Sagami Bay.

The stricken area covered 15,400 square miles, and included five big cities, thirty-three counties, and innumerable towns and villages. Japan has always had an unenviable reputation for earthquakes, and for years before this disaster the local seismographs had recorded an average of one tremor per day. Yet this did not prevent the crowding of people and the development of new businesses both in Tokio and its port, Yokohama. Tokio in 1923 had a population of 3,000,000 and Yokohama 425,000. In these teeming cities East met West. Great brick and concrete buildings rubbed shoulders with flimsy bamboo houses, whilst rickshaws jostled taxis in the streets.

Tokio Razed to the Ground

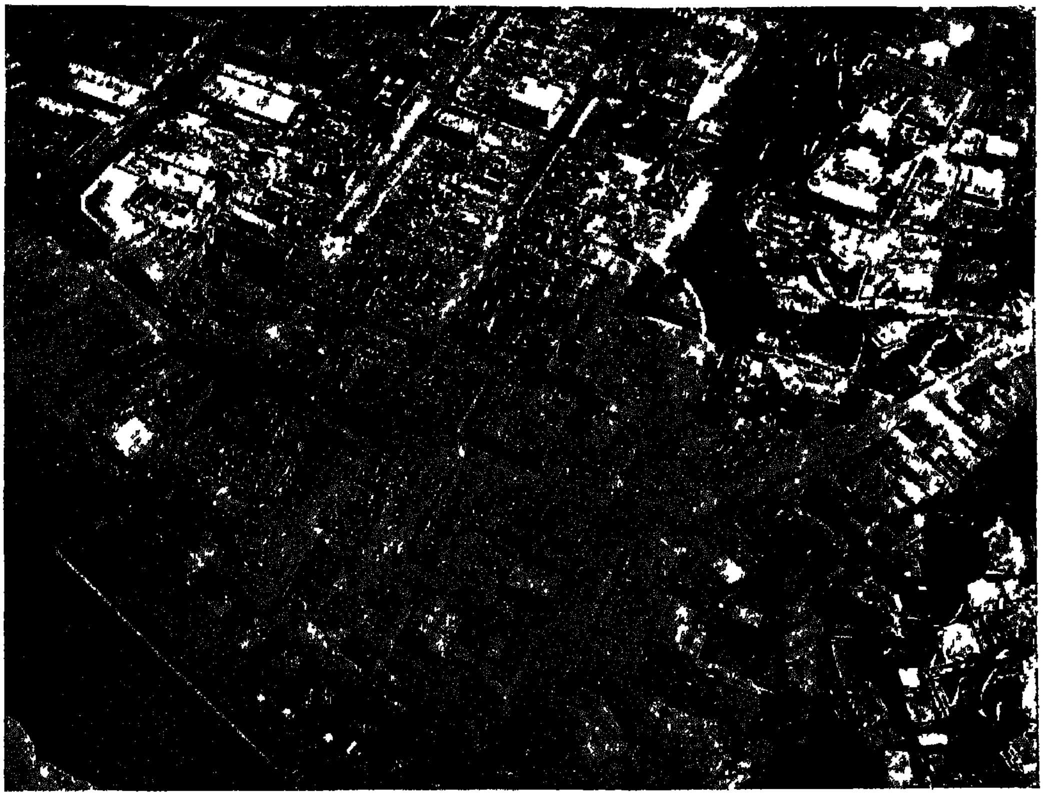
It was Saturday noon of a hot September day. Over hundreds of thousands of open braziers in wood and paper houses, Japanese housewives were cooking the midday meal. With dramatic suddenness came the first shock. The frail little bamboo houses swayed and righted themselves. The great public buildings cracked ominously. But before their occupants could rush into the streets a second, third, fourth and fifth shock were followed by five more shocks, shattering buildings into toppling ruins. The electricity works buried 600 workmen in its fall. The police office, central railway station, the banks, fell in great masses of masonry into the streets, killing and wounding thousands of terror-stricken people. More violent shocks followed. There was scarcely a building left standing.

Bamboo houses, which so far had been less affected by the shocks, became now the prey of a new horror. The braziers were overset by the continued quakings, scattering their red-hot contents on wood and lath. The occupants were caught in sudden conflagrations that burst out simultaneously in every part of the city. Fanned by a strong wind, the fires became uncontrollable. As in the San Francisco earthquake, water and gas mains burst. Many refugees, in the act of escaping by boat on canals, were burned to death when the nearby oil tanks burst.

At Yokohama, thousands took refuge from the fire by standing up to their necks in the sea. Sudden waves caused by the earthquake swept many off their feet. In the countryside beyond the two big cities the

earthquake wrought dreadful havoc. Tokio Bay and the Sumida River were flooded by a roaring wall of water which washed away hundreds of villas and demolished the seaside resort of Kamakura. In the bay all the lighthouses collapsed into the sea, and every vessel was flung on to the shore. Railways were just a mass of tangled steel, and 600 people were instantly killed by the fall of Sasako tunnel, the longest in Japan. Hills for the fire had not spared a single building. The yawning fissures in the streets were piled with 30,000 dead.

Relief ships came steaming in from all parts of the globe, bearing food and other necessities. Even drinking water had to be brought. The Japanese Emperor and the Prince Regent each gave £1,000,000 towards the relief work, and a fund was opened in London. A fortnight later the



On February 3, 1931, a serious earthquake shook the towns of Napier and Hastings in North Island, New Zealand. An air photograph of a part of Napier which suffered severe damage. In most cases buildings constructed of concrete remained standing

slipped into valleys, and the valleys that remained were loaded with debris.

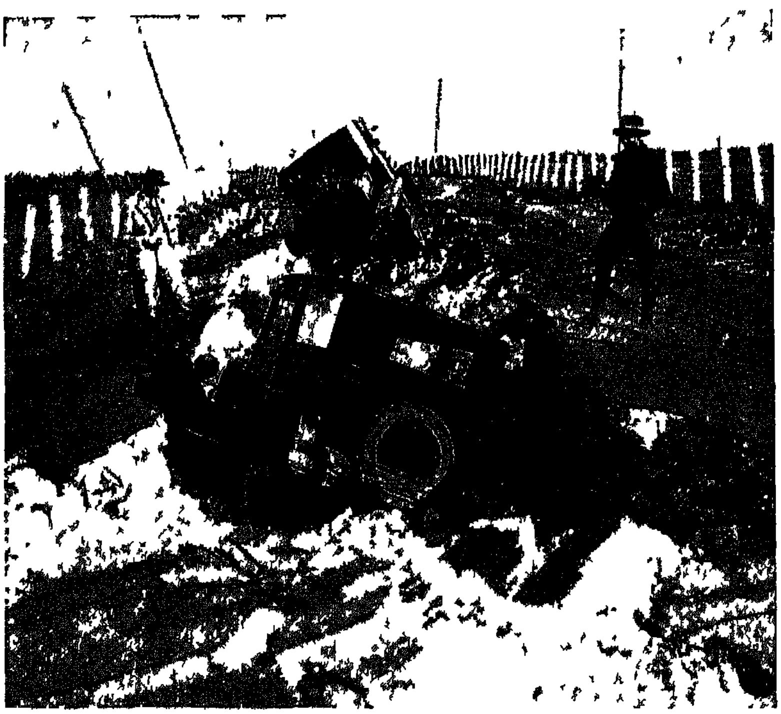
Meanwhile the merciless fire still ravaged Tokio. Crowds sought refuge in a large military clothing warehouse. Soon it was encircled by fire, and 10,000 people perished within those walls. Mothers wandered through burning streets seeking lost children. Others carried placards bearing the names of missing relatives.

Next day began a great exodus of the survivors to the hills beyond. The after-shocks could still be felt, about two every hour. Yokohama was a vast charnel house, official figures of the killed were given as 125,000. It was still another fortnight after that terrible Saturday before the quakes ceased to be felt. Altogether, 1,256 earth shocks were recorded in the months following the disaster.

To prove the correctness of seismograph calculations regarding the epicentre of the disturbance, the sea bed at Sagami was re-surveyed. Remarkable changes were found to have occurred in the contours of the ocean floor. In one place a submarine mountain 1,500 feet high had arisen; whilst close to it a depression 2,500 feet deep had been

hollowed out. The whole island of Oshima was found to have shifted twelve and a half feet in a south-easterly direction. In fact the whole district had made a clockwise twist with its pivot in Sagami Bay.

Mild indeed after such calamities as we have described seem the earth tremors that England occasionally feels. During the last thousand years only 310 have been noticed in England, and 822 in Scotland. The worst known shock was in April, 1884, and had its epicentre in the eastern counties. The church steeple at Colchester was shaken down, and hundreds of roofs and chimneys were wrecked. An earlier earthquake, in 1580, set all the London church bells ringing and shook masses of stone into the streets from church towers. It was then that England's sole recorded earthquake casualty occurred, when a London apprentice was killed by a falling stone.



During the earthquake shocks at Hastings, New Zealand, in 1931, roads caved in and great cracks appeared in which a number of motor-cars and other vehicles disappeared

The British Isles do not lie in the direct path of either of the world's two great earthquake belts. Certain observers have charted known earthquakes great and small, and found that they mainly lie along (*a*) a great belt stretching from the Mediterranean, through the Caucasus, to the Himalayas; and (*b*) the Andes-Japan-Malaya circle bordering the Pacific. Montessus, one of the observers, computed that of every 100 earthquakes, fifty-three occurred along the Mediterranean-Himalayan band, thirty-eight around the Pacific, and nine elsewhere.

An example of a serious earthquake which occurred somewhat outside the main seismic belts was that which in 1931 devastated the towns of Napier and Hastings, in New Zealand. This earthquake cannot be considered as entirely outside the Pacific ring, however, since there are certain great gaps in the main belts. The focus of the upheaval was located at some depth below the Pacific Ocean. Here it may be noted that lands situated close to ocean deeps are always in some danger of being visited by major earthquakes. The New Zealand catastrophe of 1931 is not surprising when we consider that in the Pacific Ocean northwest of the islands is situated the extensive Aldrich Deep, which shelves steeply down to the sea floor at a depth of over 4,000 fathoms. In this respect New Zealand can be compared with Japan, which has, immediately to the north, the deepest sea in the world.

The Port of Napier lies in Hawkes Bay, facing the Pacific, and Hastings almost adjoins it. The main portion of the town of Napier stretches along a flat shoreland and presented a bustling scene on the morning of February 3, 1931. The harbour was busy with men engaged in loading wool, meat and fruits into the ships lying at the wharves.

The principal shock racked the town at 10.43 a.m., destroying practically the whole of the business section and a large part of Hastings near by. Fires broke out simultaneously in many places, some in Napier being especially serious. The majority of the houses that were of wood withstood the shock fairly well, though flying furniture caused much injury and damage. But when

the fires began, the fact that so many houses were built of timber greatly increased the havoc. Buildings made of properly reinforced concrete remained standing in most cases, although the two sidewalks of the main thoroughfares caved in and taxis were swallowed as the centre of the road disappeared. Out of a total of 35,000 inhabitants, 250 were killed—145 in Napier itself—and 1,000 were injured. Over 10,000 inhabitants of the two towns were rendered homeless. Hospitals collapsed and a hostel in which night nurses were sleeping was wrecked, killing all the women as they slept.

In the bay itself many ships were stranded, for the sea bed had risen between seven and twelve feet in various places. A British naval sloop, H.M.S. *Veronica*, had a marvellous escape. It had arrived three hours before the first shock was felt. The harbour authorities indicated a certain berth for it, but the captain, with remarkable prescience, refused the berth and anchored in another one, forty yards away. When the earthquake came, it completely destroyed the berth he was originally assigned. Within fifteen minutes of the shock, bluejackets landed from the sloop and proceeded to take over the control of all supplies of food and medicine and to organize all transport.

Nineteen months later, in September, 1932, an earthquake shook Gisborne, a town in the next bay to Napier. It had slightly felt the tremors of the previous 'quake. No one was injured, but the whole town was moved several inches nearer the river by which it stood.

One of the worst earthquake disasters of recent years occurred in May, 1935, when Quetta, in British Baluchistan, was razed to the ground. For a year the remains of the city were sealed, but now it is being rebuilt at an estimated cost of £6,000,000. A section of the ruined area from the air

The Napier earthquake had been the most calamitous in the history of the British dominions until, in 1935, a far greater catastrophe devastated Quetta, a city high on the Baluchistan hills of North-west India. Quetta lies in the heart of the Mediterranean-Himalayan earthquake belt.

On May 30, at 3.04 a.m. the first shock threw the majority of the sleeping inhabitants from their beds. Terror-stricken, they fled into the streets just as the second and third tremors brought down row upon row of houses. Terrible as was the havoc, the main shock was of less than one minute's duration.

Nearly 26,000 people were killed in Quetta alone in the 1935 earthquake In less than a minute the damage done was incalculable Portions of buildings were lifted bodily and thrown some distance away and entire streets of houses collapsed (*top*)

The strong barracks which housed the police force crashed in on the sleeping men, and practically the whole body was destroyed. The native section of the city was razed to the ground, and civic buildings were an unrecognizable wreckage of debris Under the vibrations of the repeated though weakening shocks, there was soon scarcely a structure left standing. The aerodrome and R.A.F. lines suffered terribly, all buildings being demolished. Curiously enough, however, the military college some distance away was quite unharmed.

With the coming of dawn the military took charge. Martial law was proclaimed and a circle of defence thrown round the city to protect it against marauders from the hills. Sixteen thousand distraught survivors found temporary refuge on the open ground of the race-course, where food and medical services were hastily organized.

When the authorities came to examine the city itself, they found the loss of life and property far worse than they had imagined Troops worked day and night, digging in the ruins: they were able to save hundreds who had been imprisoned in the debris and whose cries could faintly be heard.

Two hundred British residents were killed, and the total deaths in the area were later given as 40,000 —nearly 26,000 in Quetta alone The remainder of the 40,000 killed came from some hundred villages that were ruined—many of them miles from Quetta, but lying along the same "fault" among the hills.

Since it was impossible to remove the bodies buried in the ruins, and because of the fear of pestilence, the whole city was

evacuated. The inhabitants were sent to other parts of the country, for a whole year only the sentries that guarded a ring of barbed wire, and the occasional commissions of inspection, lived in a place that had once been the home of 40,000 people.

Relief organizations were set up in many parts of the world, and the Lord Mayor of London inaugurated a Quetta Fund to which many large sums were contributed. The great task of rebuilding the city was begun and soon made steady progress.

Although destructive earthquakes have in recent years caused the death of hundreds of thousands and the destruction of much valuable property, the damage has almost always been greatly aggravated by attendant fires, by the bursting of gas and water mains and by the destruction of electric power lines. The more modern a city the worse the havoc seems to be. Now, however, town planners and housebuilders in seismic areas, when they rebuild cities, use the latest resources of engineering knowledge to make them as earthquake-proof as possible. Messina's tall houses have given place to lower ones. In Tokio the new public buildings are steel-framed. The piers which support bridges are made much wider at the base than normal, and the whole structure tapers rapidly as it rises. Villages are rebuilt on the hardest ground available.

CHAPTER XXX

THE FIRE-FIGHTERS

FIRE, says the old adage, is a good servant but a bad master. The total loss of life and property occasioned by fires which have spread beyond Man's control must be stupendous.

Some of the greatest disasters in history have been fires, uncontrollable in their immensity. The Great Fire of London, in 1666, burned for three whole days, destroying 436 acres of property valued at over £10,000,000. In Hamburg, in 1842, a terrible fire raged for over four days and more than 100 persons lost their lives. One-fifth of the inhabitants were rendered homeless and the property destroyed was valued at £7,000,000. Thirty years previously, the Russians deliberately burned their city of Moscow to prevent it from falling into the hands of Napoleon. During that five-day conflagration £30,000,000 worth of goods, valuables, buildings and other property were irretrievably lost. One of the greatest fires of modern times was that at Chicago in 1871. Over 2,000 acres in the heart of the city were devastated and the loss was put at £39,000,000.

Two terrible earthquake-fire tragedies have occurred in our own century. In both cases the breaking of the modern network of gas and power mains below the road surface largely contributed to the excessive destruction caused by the fire following the earthquake. The earlier was the San Francisco upheaval in 1906, where £50,000,000 worth of property was lost. The most recent was that of Tokio and Yokohama in 1923, when the total loss by earthquake and fire was estimated to be £200,000,000.

Fortunately, in these days the terrible losses are not borne entirely by those whose possessions are destroyed. Fire insurance companies compensate the small householder as well as the town council and the factory owner. The tremendous annual losses through fire are therefore not brought to the notice of the man in the street so forcibly as in earlier times, when a whole community was immediately beggared and rendered homeless by some great conflagration.

History of Fire-fighting

Efforts both to prevent and to fight fires have been made from time immemorial. The Bronze Age man with his knowledge of the usefulness of fire for smelting must often have beaten out unruly flames with tree branches or quenched them with earth, even as the fire-fighters of the prairie and forest lands do to-day.

Records of early civilizations show that fire-fighting brigades were organized to protect the property of wealthy citizens. Rome continued the practice, squads of men being trained with military precision to combat fires. These Roman firemen, of whom there were hundreds, were known as vigiles, and were divided into cohorts under the command of an officer called a siphonarius. They used machines for pumping water and even possessed a primitive form of chemical extincteur. From their siphons (or pumps) the water issued in jerks even when

these were worked at full speed; so that although capable of extinguishing a small fire, they were comparatively useless against flames which had obtained control of a building. This manual engine, as it has been termed, was the only type in use in Europe for hundreds of years after its Roman inception. Apart from the attempt both on the Continent and in England to prevent fires by the nightly ringing of the curfew bell, when all households were compelled to put out their fires and extinguish lights, few developments took place either in the organization of fire brigades or in pumping machines during the Middle Ages. In fact, the fire engine of the Romans was forgotten, and the simpler method of extinguishing fires by means of buckets of water, passed from hand to hand, usually took its place.

Large squirts or syringes to combat fires were invented during this period. They were made of brass and held some three or four quarts of water. A man held the handles at the sides and pressed the end of the piston against his chest, thus discharging the water. This was the only type of fire-fighting appliance which London possessed at the time of the Great Fire in 1666. Small wonder that all efforts to put out the mighty conflagration were of little avail in a city of narrow streets and wooden houses.

Early Fire Engines

A few years previous to the Great Fire of London, a German, named Hautsch, who lived in Nuremburg, invented a fire engine which was in principle the same as that used by the Romans. It was drawn by two horses and worked by twenty-eight men, and the pump cylinders threw a jet of water an inch in diameter to a height of eighty feet. But there was one fatal weakness in the new engine. It had to be taken very close to the fire in order to play the jet into the heart of the flames. Some fifteen years later a Dutchman, Jan Vanderheide, invented a leather hose fastened by metal rivets. When this was attached to the metal spout of the pump, the engine and its water container could effectively function farther back from the fire and was not so likely to fall a prey to the flames, as had often happened with the earlier appliance.

Side by side with improvements in the mechanical aids for fighting fires went the organization of brigades of men who made it one of their duties to work the engines when need arose. The fire insurance companies, who set up in business during the 16th and 17th centuries in England, were almost the first to supply appliances for extinguishing fires, together with the necessary firemen to work them. On the Continent at about this time similar developments took place.

By 1730 a man named Newsham in London had made a definite improvement on the German fire engine then generally used in England. He added a compressed air chamber which enabled a continuous and more powerful jet of water to be forced out of the hose and nozzle. This was the engine used by the fire-fighters belonging to the insurance companies.

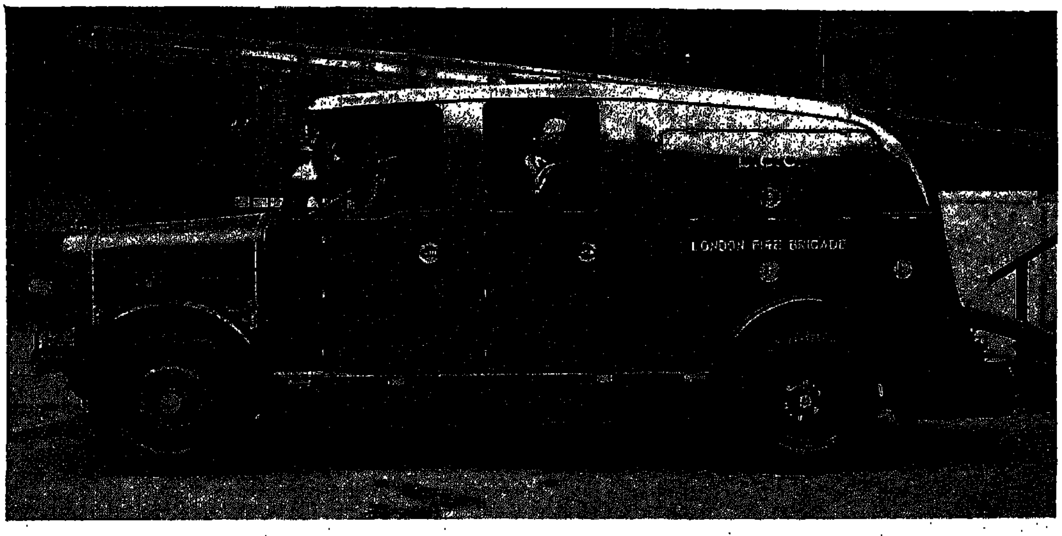
It must be remembered that the streets in those days were usually narrow and winding, and many towns were still surrounded by walls. Because of this, engines had to be built small enough to pass through the town gates. Bewdley, in Worcestershire, still possesses an old fire engine only five feet high, which was built for such a purpose.

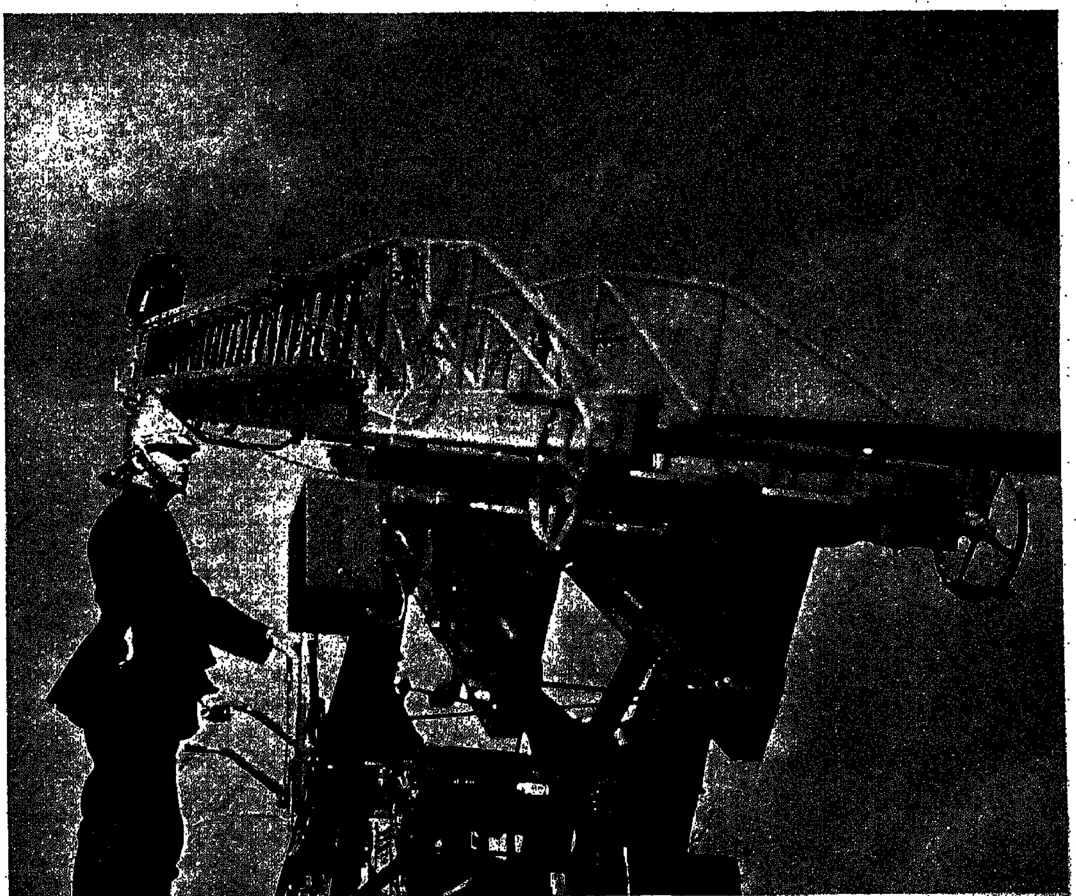
Fire Service to Protect London

In London, where the demand for fire protection was greatest, and where the insurance companies did good business, each company maintained its own brigade. Metal disks bearing the company's name were put upon all dwelling-houses or warehouses insured by them. When a fire call was sent out, only the firemen of that particular company whose mark was affixed to the house would deal with it. If they did not appear, the fire was left to burn, while rival groups stood by and watched. Such an unsatisfactory arrangement could not go on for ever, and many proposals were made for combining the fire-staffs into one big brigade. Many objections were raised, but a severe frost in 1814, when all water in the mains was frozen, forced the men to co-operate in forming "bucket chains." Eventually in 1832 what was known as the Fire Engine Establishment was formed. It controlled nineteen stations and eighty men, and £8,000 a year was required for its upkeep.

At the same time the first steam fire engine was invented by James Braidwood. It was a curious affair with boilers and pipes thrusting themselves out at all angles. Only one man instead of twenty-eight was needed to work it—which probably accounted for the vigorous opposition of the firemen to its introduction.

A serious fire in the Houses of Parliament in 1836 forced the Government to take a





The speed and efficiency of mobile fire-fighting equipment are continually being increased. This all-steel motor turntable ladder extends to a height of 70 ft, is entirely power operated and is fitted with a telephone and a powerful searchlight. The cleanly designed all-enclosed motor-pump (*top*) is the first of its type in the world. It carries a 600-gallon fire-pump, a 40-ft. extension ladder and oxygen breathing apparatus

hand in organizing and controlling the fire-protection of the ever-growing city. Parliament spent thirty years discussing the matter,

The latest type of motor turntable ladder has a loud-speaker telephone installed to facilitate communication between the control crew on the ground and the fireman operating on top of the ladder 70 ft. above

which was brought to a crisis by the terrible Tooley Street fire of 1861. This street lies just below London Bridge and was then, as now, packed with warehouses. In 1861 many of these were laden with tallow, salt-petre and sulphur, and when they caught fire, burned fiercely for well-nigh a month. James Braidwood, who was in charge of the Fire Engine Establishment, lost his life, and property estimated to be worth £2,000,000 was destroyed. The Government instituted an inquiry, which ultimately resulted in the passing of the Metropolitan Fire Brigade Act of 1865, which provided that all fire stations, engines and property, together with the fire brigades, should be transferred to the new Metropolitan Fire Brigade.

The London Fire Brigade

For the next fifty years the steam fire engine drawn by horses was used in London and in all large towns in England. In 1889 the London County Council took over the Fire Brigade, and under its supervision more fire stations were built, more appliances and engines installed, and a larger fire-fighting force trained. Altogether twenty-eight new stations were added, making a total of eighty-three in the London area, but the motorization of the Brigade, beginning in 1905, enabled the number to be reduced, so that to-day the London Fire Brigade has sixty-five stations, equipped with the finest appliances modern skill can devise.

Not only do motor-driven engines reach a fire quickly, but the motor power is instantly available to pump water. So powerful is the type of vehicle used by the London Fire Brigade that it can attain a speed of sixty miles an hour when travelling; and when used for pumping is capable of throwing a jet of water higher than St. Paul's Cathedral, at the rate of seventy-five gallons a minute. As much as five to six hundred gallons of water per minute can be delivered, but the height of the jet then is lower. The pumps are periodically overhauled and frequently tested so that they are available for use at any second of the day or night. Eighty-seven of these motor fire engines are owned by the Brigade.

At its sixty-two land stations, the Brigade has sixty-eight escape vans carrying escape ladders. In addition, there are fourteen mounted turntable ladders, capable of extending to a height of 100 feet, and of turning in a city lane a dozen feet wide. The turntables look very similar to the ordinary escapes, but when the telescoped sections are

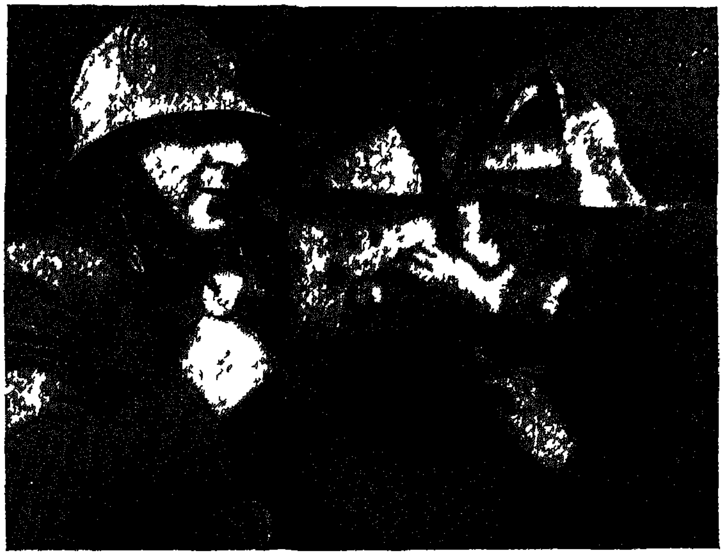
extended they support each other without the necessity of having to lean the ladder against the wall of the burning building From the top of the turntable the fireman can direct the jet of water into the very heart of the fire. Emergency tenders, "foam" tenders and generators form the remaining motor equipment, although one must not forget the canteen vans that are requisitioned to supply food and drink to the men fighting the flames. London has, too, four river floats for use at waterside conflagrations.

There are only a few emergency tenders to serve the whole of London, and one of them at least is present at every big fire. They hold accessories such as smoke helmets, breathing apparatus, electric light clusters, searchlights, suction fans for extracting smoke, oxy-acetylene cutting plant, and various tools such as hacksaws, crowbars and jacks. These vehicles, with their personnel and the wonderful plant they contain, are requisitioned also for such jobs as freeing a jammed lift or raising a vehicle that has imprisoned the victim of a road accident.

The brigade operates a service of 1,694 street fire alarms; it has 30,952 fire hydrants, and possesses 57 miles of hosepipe. The hose is made nowadays of strong canvas lined with rubber, which will take up to 300 lb. pressure per square inch. After being used at a fire it is tested for cracks or leakages, cleaned, and hung up to dry on special "towers." The fire alarms are tested every day. The testing fireman opens them with a key and uses the telephone which is attached to the alarm. The alarms are the property of the General Post Office, but the Fire Brigade is responsible for their upkeep.

How Firemen are Trained

However excellent the engines, pumps, fire alarms and other apparatus may be, they would be of little value if the men who serve in the fire brigades of any town were not strong, efficient, and well trained. Gone are the days when any willing helper, irrespective of age or efficiency, could man the fire engine. Physical fitness is an essential part of the fireman's equipment. As soon as he joins, the recruit is put through a course of training lasting from three to six months. Drill, rescuing dummies from real burning rooms, emergency descents down 100 feet of rope attached to a swaying ladder, setting up the turntable ladders, and working the pumps are but a few of the jobs the new fireman must learn in his practical work. Even the handling of a hosepipe nozzle has to be carefully practised, for it is not easy to concentrate the powerful jet on the exact spot.



Receiving instructions and transmitting reports by wireless on an engine of the Viennese Fire Brigade. *By this means the fire-fighters keep in constant touch with the Stephansturm headquarters*

Amongst other qualifications, the fireman must be a skilled engineer, and in the workshops the various appliances are taken to pieces and every man is given a course of theoretical training. Side by side with this goes instruction on the technical aspects of fire-fighting and fire-prevention. Those desiring promotion take special courses in hydraulics, building construction, advanced engineering, electricity, and applied chemistry. Drivers of the engines and tenders receive extra training not only in driving through traffic and the management of their particular vehicles, but also in the topography of the region.

The third part of a fireman's training takes place in the watchroom. This is the nerve centre of the whole station; and is linked to the control room at headquarters if the city is large. Here are the telephone connections. When a distraught house-

holder breaks the glass of a street fire alarm and pulls the knob inside, he sets an alarm bell ringing in the watchroom of the nearest fire station. Immediately, the man on duty switches on the "call lights"—coloured signal lamps indicating what appliances must be rushed to the fire. He warns the nearest station to send a motor pump, informs headquarters of the alarm, notes the exact time and records the number of men sent out; then he waits ready for further reports from the scene of the fire or for calls from any other outbreak. It is not an heroic task, but it is a very necessary one, for on the watch-duty officer depends the speed with which the call is answered and the effective co-operation between headquarters and the men at the scene of the fire.

Choking smoke and poisonous fumes are among the greatest dangers the fire-fighters have to face. The London Fire Brigade has recently been trying out special smoke helmets and breathing apparatus designed to combat this menace. The latest type of motor pump is fitted with this new equipment

The first appliance to leave the station is the escape van, since the saving of life is the first duty. The average time in turning out an escape manned by four men is twenty seconds. Within the space of two or three minutes after arrival at the scene of the fire the ladders have been unshipped and placed into position, and the firemen may be descending them with the unfortunates who were trapped in the burning building.

In narrow alleys, or if the fire is exceptionally fierce, jumping sheets are used. These jumping sheets are made of canvas and are some ten feet in diameter, being fitted with twenty-four handles.

Meanwhile the pump and hose are being prepared. One man tends the pump; another may search neighbouring walls for the nearest plate bearing the sign H. for hydrant —though probably he is already familiar with the location of these; two others unroll the coils of hose, coupling them together to the requisite length. Another, if possible, enters the burning building to locate the seat of the fire and get some idea of the plan of the premises.

As soon as the hose jet is working, a call is put through for assistance if the officer in charge deems the fire too large for him to cope with. Should he give a "District" call —we are taking the London area as an example—some fifteen appliances are sent to the scene of the fire from other stations in that division of the city. If a "Brigade" call is necessary, the demand for additional forces goes direct to headquarters. On the wall of the control room of the London Fire Brigade is a great map of the County of London. Every fire station is marked on it, and the number of appliances with which it is supplied. A small peg represents each of the appliances, so that when the engines have been sent to a fire, the chief officer can see by a glance at his pegged map which areas can best spare the requisite type of engine. The remaining forces have then to be temporarily rearranged so that, in the event of another outbreak of fire, no region

is left unguarded. So highly organized is the Brigade that it is possible to concentrate ninety-two fire appliances at one point and still maintain a skeleton service in all the other districts.

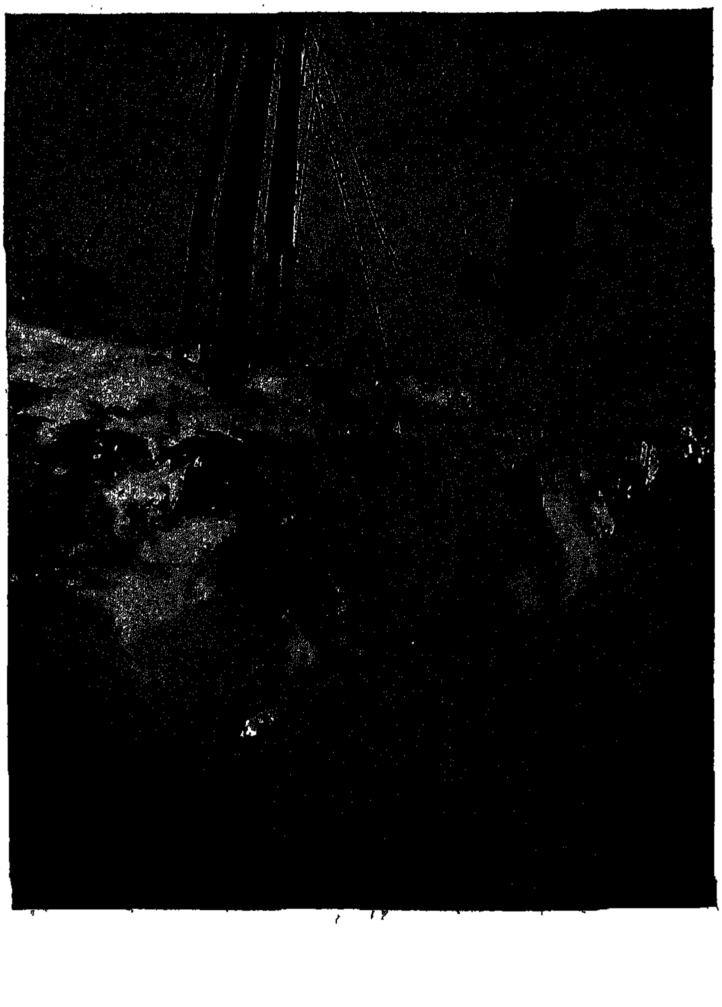
The powers of a Fire Brigade Officer in charge at the scene of a fire are absolute. Naturally he works in conjunction with the senior police officer and a salvage officer who are in attendance. He may break into premises, remove interferers, or even order the water supply for a district to be cut off so that an increase will be available at the fire. His chief problem, after all has been done to save life, is to prevent the conflagration from spreading. He has to shoulder blame for undue damage caused by water, or undue destruction by other means. A small fire, or one caught in the early stages, is easily quenched; but once an outbreak has obtained a firm hold, it is often impracticable to do more than confine it within the smallest possible space, and let the conflagration burn itself out.

About 17,000,000 gallons of water are used by the London Fire Brigade to fight fires each year, and the Metropolitan Water Board makes no charge for it. But though he may be lavish with the water, it must not be wasted, and the officer in charge has to be careful that it is employed to the best effect. Subordinate officers watch at various vantage points for fresh outbreaks, and unsafe walls, and see that the firemen are not put to unreasonable risk while carrying out their various tasks.

Firemen encounter some of their most formidable and perilous tasks when subduing fires in big warehouses, which often contain goods of a highly inflammable nature. Here are four fire-towers in action at a serious warehouse conflagration at Colonial Wharf, Wapping

Firemen penetrate right into the heart of the fire as soon as it is under control, dragging in great lengths of hose in order to play the jets at closer quarters. They always go in pairs, since the danger from blazing woodwork, molten metal or collapsing walls is exceptionally great. The Salvage Corps is another body of men who play an important part in lessening the loss by fire. Only such large cities in Britain as London, Liverpool and Glasgow possess such a corps. In New York and the bigger American cities there are similar bodies called Fire Patrols, while the salvage corps of Paris is under the orders of the Fire Brigade. The London Salvage Corps numbers about 100 men and is managed and maintained jointly by the principal insurance companies. The men can be distinguished from firemen by their black helmets; and their equipment consists of tarpaulins, axes, handpumps, brooms, "swabs," buckets and sponges. While the firemen are busily extinguishing a fire which

Corn, hay and similar vegetable matter burn fiercely and frequently go on smouldering for days. Fires of this kind may be impressive to watch but they make heartbreaking work for the fire-fighters, who are *seldom* able to save anything from the flames. Part of a fire in which thirty corn-stacks were destroyed and (*right*) a steamer with a cargo of grass ablaze in Liverpool Docks



has broken out in a shop, warehouse or factory, the salvage men are inside the premises working at breakneck speed to prevent damage to property. They spread tarpaulins over merchandise, move goods away out of danger and clear gutters of debris that would impede the drainage of water from the building. When the fire is extinguished and the firemen leave, the salvage men must make every effort to dry the building, and one or two remain to guard the salved property until the owners' claim is considered by the insurance company. The water, of course, may do as much damage to goods as the fire itself.

Among recent developments in fire-fighting appliances is the use of chemicals and gases, not-